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SUMMARY TECHNICAL REPORT
OF THE
NATIONAL DEFENSE RESEARCH COMMITTEE

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SUMMARY TECHNICAL REPORT OF DIVISION 6, NDRC

VOLUME 4

METHODS AND DEVICES DEVELOPED FOR THE SELECTION AND TRAINING OF SONAR PERSONNEL

OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT
VANNEVAR BUSH, DIRECTOR

NATIONAL DEFENSE RESEARCH COMMITTEE
JAMES B. CONANT, CHAIRMAN

DIVISION 6
JOHN T. TATE, CHIEF

WASHINGTON, D. C., 1946

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NOTES ON THE ORGANIZATION OF NDRC

The duties of the National Defense Research Committee were (1) to recommend to the Director of OSRD suitable projects and research programs on the instrumentalities of warfare, together with contract facilities for carrying out these projects and programs, and (2) to administer the technical and scientific work of the contracts. More specifically, NDRC functioned by initiating research projects on requests from the Army or the Navy, or on requests from an allied government transmitted through the Liaison Office of OSRD, or on its own considered initiative as a result of the experience of its members. Proposals prepared by the Division, Panel, or Committee for research contracts for performance of the work involved in such projects were first reviewed by NDRC, and if approved, recommended to the Director of OSRD. Upon approval of a proposal by the Director, a contract permitting maximum flexibility of scientific effort was arranged. The business aspects of the contract, including such matters as materials, clearances, vouchers, patents, priorities, legal matters, and administration of patent matters were handled by the Executive Secretary of OSRD.

Originally NDRC administered its work through five divisions, each headed by one of the NDRC members. These were:

Division A—Armor and Ordnance
Division B—Bombs, Fuels, Gases, & Chemical Problems
Division C—Communication and Transportation
Division D—Detection, Controls, and Instruments
Division E—Patents and Inventions

In a reorganization in the fall of 1942, twenty-three administrative divisions, panels, or committees were created, each with a chief selected on the basis of his outstanding work in the particular field. The NDRC members then became a reviewing and advisory group to the Director of OSRD. The final organization was as follows:

Division 1—Ballistic Research
Division 2—Effects of Impact and Explosion
Division 3—Rocket Ordnance
Division 4—Ordnance Accessories
Division 5—New Missiles
Division 6—Sub-Surface Warfare
Division 7—Fire Control
Division 8—Explosives
Division 9—Chemistry
Division 10—Absorbents and Aerosols
Division 11—Chemical Engineering
Division 12—Transportation
Division 13—Electrical Communication
Division 14—Radar
Division 15—Radio Coordination
Division 16—Optics and Camouflage
Division 17—Physics
Division 18—War Metallurgy
Division 19—Miscellaneous
Applied Mathematics Panel
Applied Psychology Panel
Committee on Propagation
Tropical Deterioration Administrative Committee

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NDRC FOREWORD

As events of the years preceding 1940 revealed more and more clearly the seriousness of the world situation, many scientists in this country came to realize the need of organizing scientific research for service in a national emergency. Recommendations which they made to the White House were given careful and sympathetic attention, and as a result the National Defense Research Committee [NDRC] was formed by Executive Order of the President in the summer of 1940. The members of NDRC, appointed by the President, were instructed to supplement the work of the Army and the Navy in the development of the instrumentalities of war. A year later, upon the establishment of the Office of Scientific Research and Development [OSRD], NDRC became one of its units.

The Summary Technical Report of NDRC is a conscientious effort on the part of NDRC to summarize and evaluate its work and to present it in a useful and permanent form. It comprises some seventy volumes broken into groups corresponding to the NDRC Divisions, Panels, and Committees.

The Summary Technical Report of each Division, Panel, or Committee is an integral survey of the work of that group. The first volume of each group's report contains a summary of the report, stating the problems presented and the philosophy of attacking them, and summarizing the results of the research, development, and training activities undertaken. Some volumes may be "state of the art" treatises covering subjects to which various research groups have contributed information. Others may contain descriptions of devices developed in the laboratories. A master index of all these divisional, panel, and committee reports which together constitute the Summary Technical Report of NDRC is contained in a separate volume, which also includes the index of a microfilm record of pertinent technical laboratory reports and reference material.

Some of the NDRC-sponsored researches which had been declassified by the end of 1945 were of sufficient popular interest that it was found desirable to report them in the form of monographs, such as the series on radar by Division 14 and the monograph on sampling inspection by the Applied Mathematics Panel. Since the material treated in them is not duplicated in the Summary Technical Report of NDRC, the monographs are an important part of the story of these aspects of NDRC research.

In contrast to the information on radar, which is of widespread interest and much of which is released to the public, the research on subsurface warfare is largely classified and is of general interest to a more restricted group. As a consequence, the report of Division 6 is found almost entirely in its Summary Technical Report, which runs to over twenty volumes. The extent of the work of a Division cannot therefore be judged solely by the number of volumes devoted to it in the Summary Technical Report of NDRC: account must be taken of the monographs and available reports published elsewhere.

Any great cooperative endeavor must stand or fall with the will and integrity of the men engaged in it. This fact held true for NDRC from its inception, and for Division 6 under the leadership of Dr. John T. Tate. To Dr. Tate and the men who worked with him—some as members of Division 6, some as representatives of the Division's contractors—belongs the sincere gratitude of the Nation for a difficult and often dangerous job well done. Their efforts contributed significantly to the outcome of our naval operations during the war and richly deserved the warm response they received from the Navy. In addition, their contributions to the knowledge of the ocean and to the art of oceanographic research will assuredly speed peacetime investigations in this field and bring rich benefits to all mankind.

The Summary Technical Report of Division 6, prepared under the direction of the Division Chief and authorized by him for publication, not only presents the methods and results of widely varied research and development programs but is essentially a record of the unstinted loyal cooperation of able men linked in a common effort to contribute to the defense of their Nation. To them all we extend our deep appreciation.

Vannevar Bush, Director
Office of Scientific Research and Development

J. B. Conant, Chairman
National Defense Research Committee

FOREWORD

FOLLOWING THE organization of Division C in the spring of 1941, it soon became apparent that the Division could offer valuable assistance to the Navy in activities other than those originally contemplated. Among these was the selection and training of personnel, the subject of this report. In October 1941, Captain Lybrand Smith, Assistant Coordinator of Research and Development, wrote to Dr. F. B. Jewett, Chairman of Division C, in part as follows:

> Everybody concurs in the opinion that it is desirable to study and formulate aptitude tests for personnel who are to be trained for the operation of sonic and supersonic apparatus and to formulate improved training programs for such persons. Therefore, it is requested that NDRC undertake this work.

This request was formally accepted by the NDRC in November 1941 and assigned to Section C-4. Steps were promptly taken to organize this work. At the request of Dr. J. T. Tate, Dr. G. P. Harnwell, serving as Technical Aide, undertook to review the problem and to recommend plans for NDRC participation. Largely on the basis of Dr. Harnwell's findings, a committee on the Selection and Training of Sound Operators was appointed in December 1941 to study various aspects of the training program in cooperation with Navy personnel and to recommend action to the Division. Members of the Committee were Dr. Viteles, Dr. Wever, Dr. Wilks, Dr. Fry, and Mr. Shea, with Dr. Harnwell as chairman.

An initial training group was set up at the University of California laboratory at San Diego. As the work of the Division expanded, training groups were established at other laboratories and the scope of activities broadened. During 1942 and 1943 the major emphasis of the program was on the selection and training of ASW sonar personnel, whereas during 1944 and early 1945, equal or even greater emphasis was given to the training of submarine personnel.

The following volume summarizes the principal activities and accomplishments of the Selection and Training groups in the field of subsurface warfare. That these civilian groups were able to make significant contributions to what had always been considered purely military activities is a tribute to the wise guidance of Dr. Harnwell and his associates. The Division also wishes to record its appreciation to Dr. Harnwell, as well as to Dr. W. D. Neff and Dr. M. C. Towner, for the collection and preparation of the material included in this volume. In this work, they were assisted by the editorial staff of the Columbia University Summary Reports Group.

JOHN T. TATE
Chief, Division 6

PREFACE

THIS VOLUME, dealing with methods and means for selecting and training Naval sonar officers, operators, and maintenance men, summarizes activities undertaken by a number of laboratories and independent groups operating under Division 6. Unfortunately, limitations in time and available personnel have not permitted the preparation of an integrated well-balanced text on this subject. Consequently, the following pages must be regarded rather as a final report of the groups and laboratories concerned. It is hoped, however, that much of value will be derived from the volume, both by military and by civilian groups having kindred problems in the training of large groups to perform specialized tasks.

The volume is divided into two parts. The first covers the methods of selection and training, and was prepared by Dr. W. D. Neff, with the assistance of Dr. W. L. Jenkins and Dr. R. L. French of the Columbia University laboratory at New London. Basic material was furnished by Dr. J. Morris, Dr. Hartig, and Dr. Ford.

The second part of the volume describes in some detail the physical devices developed by the several laboratories to serve as training aids for individual or group instruction. Most of this material was prepared originally under the direction of Dr. Towner, with final editing by the staff of the Columbia University Summary Reports Group.

J. S. COLEMAN

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Chapter 1

INTRODUCTION

1.1 SELECTION AND TRAINING OF ANTISUBMARINE PERSONNEL

At the first meeting with the Committee on Selection and Training, December 4, 1941, representatives of the Navy very fully and helpfully outlined the problems faced in selecting and training a sufficient number of sonar operators to meet their rapidly increasing requirements. By the time of the second meeting, January 2, 1942, the Navy had made new plans calling for a several fold increase in our antisubmarine warfare [ASW] forces, and the problems of selection and training had become still more urgent.

1.1.1 Selection

The development of methods whereby better students could be selected for the sound operator courses given at the West Coast Sound School, San Diego, and the Fleet Sound School, Key West, was undertaken as the most immediate means of improving the quality of sonar operators. At a later date, the selection of maintenance men was studied, and, still later, that of sonar officers.

Sonar Operators. Members of the committee visited the Navy sound schools and made a preliminary analysis of the sonar operator's job. A number of standard aptitude tests which were readily available were administered experimentally to sonar operator classes entering the schools. An initial selection scheme using the tests[a] which best predicted success in the operator course was put into effect at naval training centers in April 1942. In spite of the emergency haste with which this first test battery was chosen, results justified its adoption; the number of student failures was immediately reduced and the general caliber of the men sent to the school was quite obviously raised.

Research to improve the initial selection plan was continued throughout 1942, 1943, and part of 1944. Studies were made of additional factors such as age, amount of education, nearvision, and threshold hearing to determine their importance in operator selection. A final selection scheme, adopted in 1944, was a somewhat refined version of the original scheme, with added emphasis on the auditory tests. Repeated checks indicated that the sonar operator selection methods were successful in choosing men who could successfully pass the sonar operator courses.

Maintenance Men. In the summer of 1942, research on selection of sonar maintenance men was started independently at the two sound schools. The problem was to pick the graduates of the sonar operator course who were most likely to be successful in the maintenance course. Essentially similar procedures were adopted at both San Diego and Key West. Standing in the operator course, grades on tests of mathematical and mechanical comprehension, years of education, and evidence of interest in radio and electricity were found to be significant factors. At both schools, the selection methods adopted reduced substantially the number of failures in the sonar maintenance course.

Sonar Officers. In May 1943 Division 6 was asked to extend its work to include research on the selection of sonar officers. Two studies were made, the first completed in September 1943 and the second in July 1944, but neither gave conclusive results. The attempt to validate a test battery was hampered by the difficult conditions under which tests had to be administered, by the lack of reliable criteria, and by the preselection of the experimental groups. A tentative selection scheme was suggested but the demands of the sonar officer training program did not warrant its adoption.

1.1.2 Training Assistance to Navy Sound Schools

Concurrently with the research on selection, assistance was being given in developing the training programs at the sound schools in San Diego and Key West. Early in 1942, personnel to assist in development of training methods were assigned to both schools and a section of the University of California Division of War Research [UCDWR] laboratory at San Diego was given over to the design of synthetic trainers. During 1943 the work of these groups reached a peak; it continued, but at a lower priority, through 1944 and the spring of 1945.

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[a] The Navy GCT, the Bennett Mechanical Comprehension Test, and the Pitch and Tonal Memory Tests from the Seashore Measures of Musical Talent.

Curriculum Planning. Directly or indirectly, the training personnel at both schools made a continuous effort to revamp course schedules. At first, their efforts were limited to specific suggestions for correcting obvious defects, such as the elimination of unsupervised study and needless stand-by time. Later, as they became more intimately acquainted with the problems of the schools, the training groups worked directly with instructors in planning major revisions in course schedules. An increase in the supply of standard equipment and synthetic training devices permitted greater emphasis to be placed on operating drills and laboratory work.

Achievement Testing. The inadequacy of the methods being used to measure student achievement first became manifest when school grades were examined as criteria for validating selection tests. Reliable measures of student *knowledge* were soon provided in the form of standardized objective written examinations, but measures of student *performance* were more difficult to achieve. The better synthetic trainers were designed so as to provide direct measures of performance. For other trainers and for standard equipment on training ships, checking systems were devised which enabled the instructor to check or rate the student on each part of a series of complex operations. The checking systems were not only useful for grading but also for showing up weak spots in training.

Instructor Training. Assistance in the training of Navy instructors was largely informal. Members of the training groups helped instructors plan their lectures and drills and coached them in effective methods of presentation. The introduction of new equipment and of new synthetic training devices provided many opportunities to demonstrate better teaching methods. The effectiveness of instructor training was severely limited, however, by the system of instructor rotation. Retention of good instructors for longer periods would have permitted more thorough training and greater teaching efficiency in the schools.

Preparation of Training Aids. Instruction books, phonograph recordings, slides and films, wall charts, and miscellaneous devices were produced in quantity. The laboratories provided instruction books on operation and maintenance of new equipment and instructor's handbooks for synthetic trainers. The groups stationed at the schools assisted in the preparation of more general textbooks for classroom use.

Perhaps the most valuable training aids developed were phonograph recordings of underwater sounds. Some 300 finished recordings were made for ASW sonar training. The first of these contained examples to be used for classroom demonstrations; then, in order to increase student participation, drill and test recordings were prepared; and ultimately, special trainers were designed so that an instructor could continuously monitor the students during recording drills.

Construction of Synthetic Trainers. In order to overcome the serious shortage of practice equipments, first efforts were concentrated on design of synthetic trainers which could be turned out in quantity and in a hurry. Bearing teachers which simulated many of the operations of the standard sonar stack were produced during 1942. Experience with these first individual trainers led to the development during 1943 and 1944 of group trainers, each having a central control station from which an instructor could direct and monitor a group of 10 to 20 students. The later synthetic trainers also provided more realistic sounds and better methods of scoring performance.

1.1.3 Assistance to Navy Activities Other Than Sound Schools

Although much of the assistance given by the Division 6 selection and training groups concerned the two sound schools, work outside the schools grew to occupy an important place in ASW sonar training. In 1943, a training representative was assigned to the Readiness Section, COMINCH 10th Fleet. Later that year and during early 1944, similar liaison men were assigned to COTCLant and ComDesPac. Members of the school and laboratory training groups also made frequent visits to other training activities to assist in the installation of training equipment and in the initiation of programs for use of new synthetic trainers.

1.1.4 Training Programs to Introduce New Laboratory Developments

The laboratories of Division 6 were primarily engaged in research leading to the development of new devices for combat use. When the very first units of such devices were produced and turned over to the Navy, it became evident that the laboratories themselves would have to take an active part in initiating training programs for the Service personnel who were to operate and maintain the new equipment.

It was desirable to use the knowledge and experience of the research engineers without burdening them with the actual tasks of training. Consequently, groups were organized at the laboratories to work specifically on the problems of training. It was the function of these groups to plan suitable training courses, prepare necessary training aids and devices, and provide the field services needed to introduce the training courses at Navy activities.

BDI Training. The *bearing deviation indicator* [BDI], providing accurate and continuously centered target bearings, was developed by the Harvard Underwater Sound Laboratory [HUSL]. The introduction of BDI necessitated suitable training for sonar operators, maintenance men, and officers. For operators, experimental models were made of three different synthetic trainers, one of which was produced in quantity. Maintenance courses for field engineers who were supervising BDI installations were given at the laboratory, and a course for ASW specialists was outlined in collaboration with the Antisubmarine Warfare Instructors' School [ASWIS], Boston. Experiments to develop conning procedures using center bearings were conducted by laboratory personnel in collaboration with AsDevLant.

ERSB Programs. The *expendable radio sono buoy* [ERSB] was an airborne antisubmarine device developed by the Columbia University Division of War Research [CUDWR] laboratory. To insure the effective use of this device, an extensive training program was conducted by laboratory training and development groups. During late 1942 and 1943, before production units of ERSB were in use, instruction manuals and recordings were prepared and a training course for several groups of instructors was given. Later a slide film describing the buoy equipment and its use was produced and distributed. Instruction books and recordings were revised and reissued.

An even more important factor in training Navy personnel who used ERSB equipment was the widespread efforts of a special ERSB field group. These men provided both engineering and training assistance. They visited all bases where buoy equipment was in use, started training courses, helped install equipment, and made flights to try it out and to give crew training. They also made trips on carriers into combat zones in order to service equipment and train the plane crews using it. Their activities carried them to bases in the Atlantic, Mediterranean, Caribbean, and Pacific.

In 1944 a sono buoy school was established by ComAirLant at Norfolk, Virginia. A synthetic trainer was constructed for this school, instructors were trained, and assistance was given in planning courses.

During 1944 and early 1945, in anticipation of its Service use, a training program for a modified buoy was started. By this time, however, the job was greatly simplified, since the ComAirLant school was ready to give training courses and the Aircraft Coordinating Group, BuShips was carrying on the work formerly done by the ERSB field group. Instruction books, recordings, a movie, and a synthetic trainer were produced and turned over to these groups for use, and a special course for instructors was conducted at the New London laboratory.

BT Program. The *bathythermograph* [BT] developed by Woods Hole Oceanographic Institution [WHOI] made possible the prediction of sound ranges under various oceanographic conditions. Training was required for the officers who were to use BT and, to a lesser extent, for technicians who were to service it. Some instruction was given at WHOI to special groups, but the major emphasis was on field work. During 1942 and 1943, WHOI representatives made regular visits to training activities and ASW ships. In 1944, an intensive program of refresher instruction and manual revision was organized by UCDWR in collaboration with BuShips. BT pilot instructors traveled from one Navy activity to another giving instruction on new BT developments. Work was started on a series of BT manuals which were to include up-to-date information derived from oceanographic research.

MAD Training. The *magnetic airborne detector* [MAD] was developed by the Airborne Instruments Laboratory [AIL], Mineola, and practically all training in the use and maintenance of MAD was carried out by the laboratory. It was necessary to train radio operators in the interpretation of MAD indications, pilots in methods of search and tracking, and technicians in upkeep and repair. Courses for these three purposes were taught by laboratory personnel during 1943 and 1944. A simple training device was constructed to teach pilots the rudiments of MAD tactics and a more elaborate trainer, simulating MAD search and attack conditions, was built to give team training to pilots and MAD operators.

1.2 SELECTION AND TRAINING OF SUBMARINE PERSONNEL

By late 1943, efforts, particularly at New London, were being directed towards the development of equipment, principally sonar, for submarines. In the selection and training work a corresponding shift in emphasis took place. Only a limited amount of work was done, however, on selection of submarine personnel. Primary concern of the Division 6 groups was with training. Here the background of two years' experience in ASW work was a valuable asset; it made possible the rapid development of well-integrated effective training programs.

Assistance to the submarine forces in the selection and training of personnel was continued by Division 6 until termination of its activities in June 1945. After that date, several of the groups which had formed part of Division 6 carried on similar work under direct contracts with the Navy. A submarine training section was established at New London under a contract between Columbia University and the Bureau of Naval Personnel; a second group, under a University of California-BuShips contract, maintained assistance to WCSS; and WHOI, under BuShips contract, continued to aid in BT training.

1.2.1 Selection

For a short period during 1942, a representative of Division 6 worked with the Medical Research Department, Submarine Base, New London, on sonar operator selection. On several later occasions, assistance was provided in the form of consultation on selection procedures or construction of special testing equipment.

Selection of submarine sonar operators was considered a relatively unimportant problem. The sonar operator did not play the major role on submarines that he did on ASW surface craft. There were no rated sonarmen until 1945 and then only a few. Commanding officers filled the sonar watches by assigning men of other rates who were not occupied full time. As a consequence, the system followed in the submarine schools was to give sonar operator training to all men, or to as many as possible, who might be called upon to stand sonar watches. The problem then was not one of selecting the men best qualified to be sonar operators but simply one of eliminating those men who might be potentially dangerous because of marked deficiences of hearing, speech, or motor coordination.

From July 1944 to January 1945, a group from the CUDWR laboratory was stationed at Pearl Harbor to work with ComSubTrainPac on selection and training problems. Their chief contribution was the establishment of a system whereby (1) all men assigned to ComSubPac were classified on the basis of standard Navy tests, education, experience, and interest, and

(2) entrance standards were set for all courses given by ComSubTrainPac. In this way, waste of training facilities on unqualified men was largely eliminated. The work started by the CUDWR group was continued by a Selection and Training Officer added to the ComSubTrainPac staff.

1.2.2 Training

In the ASW work, assistance had been provided first in one aspect of training and then in another to meet new demands as they arose. Too often there was a lack of integration of efforts of several groups working on related problems. Profiting by the ASW experience the Division 6 training groups followed a more orderly procedure in attacking submarine problems. Requests for specific assistance of a limited nature were sidetracked in favor of those for assistance in revamping or establishing entire programs. The development of each new training program included the following steps.

1. Analysis of training requirements.
2. Survey of existing facilities.
3. Planning of curricula.
4. Training of instructors.
5. Development of achievement tests.
6. Preparation of training aids.
7. Construction of synthetic trainers.
8. Field service to introduce the new program.

Complete programs of this nature were successfully carried out for sonar, voice communications, and radar training.

Sonar Training. Submarine sonar training expanded rapidly during 1944 and early 1945. Division 6 assisted in the planning and establishment (1) of new basic courses for sonar operators at Pearl Harbor, New London, and San Diego; (2) of a basic maintenance course at New London; and (3) of refresher courses for operators and maintenance men at Pearl Harbor, Perth, and New London. Special courses were established at a number of other submarine bases.

Operator and maintenance training for JP sonar, an equipment developed by the CUDWR laboratory, was begun prior to the more general expansion of submarine sonar training. Laboratory representatives prepared training materials and introduced JP courses at submarine bases in both the Atlantic and Pacific. Training for other sonar equipments developed by Division 6 laboratories came at a later date and was added to existing sonar courses. Laboratory training groups wrote operator and maintenance instruction books, made recordings, built trainers, and outlined suggested courses. In each instance these training materials were distributed to training activities prior to the installation of production equipments on submarines.

Voice Communications Program. In order to fulfill a request of ComSubsLant for assistance in developing voice communications training, Division 6 enlisted the aid of two other NDRC groups, namely, Psycho-Acoustic Laboratory at Harvard University and Project N-109 of the Applied Psychology Panel. The three groups collaborated in a twofold program which involved (1) standardization of phraseology and procedures used in voice communications and (2) establishment of training courses for officers and men.

Work was begun in April 1944 and concluded in December. By that time a catalogue of standard commands and reports, an instruction book on basic procedures, and a ship's organization chapter had been prepared and issued. Basic, intermediate, and advanced training courses had been started. Instructors had been trained to give the voice communication courses at advanced bases, and equipment for training rooms had been assembled and shipped to these bases.

Submarine Bathythermograph Program. Bathythermographs provided information useful to submarines both in predicting sound ranges and in diving. From early 1942 until termination of Division 6 work in 1945, assistance was given in the training of diving officers, sonar officers, and maintenance men. The assistance was chiefly of two kinds—field instruction and preparation of manuals.

Representatives of the WHOI and UCDWR laboratories visited submarine bases in both the Atlantic and Pacific to assist in installation of equipment and to give training in its use and maintenance.

A series of instruction books were written by WHOI and UCDWR, printed by BuShips, and distributed to all submarine activities.

1.3 SUGGESTIONS

The Division 6 groups worked for three and a half years on problems of selecting and training Navy personnel during a wartime emergency. A brief summary of this work has been given and a more detailed account is presented in the chapters which follow. For the future of Navy selection and training tentative conclusions arising from the experiences of the Division 6 groups are suggested.

1.3.1 Selection

Under wartime conditions true selection research is impractical. Experimental conditions cannot be controlled adequately and the pressure to obtain positive results and to apply them immediately is too great. Carefully planned research programs should be carried on in time of peace so that selection plans are ready for immediate use if an emergency arises. In time of war, selection research should have only two aims: (1) continual verification of the procedures in use; (2) solution of the new and unexpected problems which are bound to arise.

The selection of men for any particular specialty, such as sonarman, should be only a phase of a much broader program, that is, the classification and assignment of all men on the basis of their aptitudes, experience, education, and interests. Only such a general program can make the most efficient use of available manpower and avoid the waste and confusion which occurs when various specialties compete for the best men.

Comments on the specific selection problems which were encountered by Division 6 are given at the ends of Chapter 2 and Chapter 4.

1.3.2 Training

Although the Navy training programs in which Division 6 participated were effective, as evidenced by the success of the groups to whom training was given, there were a number of serious deficiencies which deserve future consideration.

Operational Research. A constant handicap in the development of training courses was the lack of the particular kind of operational research necessary (1) to evaluate new equipment from the standpoint of ease in using and maintaining it and (2) to formulate new doctrines and procedures governing its use.

Early in its development each new or modified equipment should be given field tests to answer such questions as the following. How convenient is the arrangement of controls which the operator manipulates; how legible are the meters and dials; can controls, meters, and dials be rearranged so as to simplify operation; does the equipment cause excessive operator fatigue; are parts readily accessible for maintenance; can whole units be quickly replaced; is the design such that trouble shooting can be entrusted to a relatively inexperienced technician; are there features which add excessively to operating or maintenance difficulties? These and similar questions are of the utmost importance when operators and maintenance men must be trained quickly. They are also important for the final success of the equipment under actual operating conditions. Answers should be clearly determined before the design of new equipment is frozen for production.

Most innovations in equipment necessitate changes in operational procedures and tactics. Adequate new doctrines can be developed only through experiments under realistic field conditions. Neglect of this aspect of research means that old doctrines continue to be taught until the equipment has been in use for some time, or new doctrines are established on the basis of opinion rather than facts. In either case, the result is delay in the effective use of the new equipment. Two typical instances of such delays can be cited. BDI equipment had been installed on ASW ships for several months before an adequate conning doctrine based on center bearings was established. Almost a year was lost before the full potentialities of the sound range recorder were discovered incidentally in the course of research on forward throwers.

Administration. The officers placed in charge of schools and training courses were, almost without exception, unfamiliar with the standard methods of education and school administration which have long been accepted in civilian schools. It is as unfair ,to expect a Navy officer without special training to administer a school as it is to expect a superintendent of schools to command a ship. The frequent rotation of school administrators only added to the fundamental weakness of the system. About the time an officer had begun to learn something about his job, he was transferred and a new man took his place.

An important step forward for the Navy educational system would be to put the direction of its schools into the hands of men professionally qualified as educational administrators. This might be accomplished in several ways. Selected Navy officers could be given advanced training in educational administration. Professional educators could be commissioned as Navy officers. Or civilian specialists could be employed as school administrators.

Planning of Training. To be effective, training courses must be planned on the basis of facts. How many men are needed and at what rate? What knowledge must they be given? What skills must they acquire? How long will it take them to gain sufficient knowledge and skill? How many instructors and how much equipment are necessary to train the number of men in the time allowed? These and many other questions must be answered as accurately as conditions permit. Then the course can be planned to accomplish the desired aims.

Unfortunately, Navy courses were not always planned this way. As an example, take the ASW sonar operator course. It was established as a five-week course in the spring of 1942. Two years later, it was still a five-week course although there had been added to the operator's job: operation of the sound range recorder, rudiments of plotting and use of BDI. In sonar maintenance, men with no experience or training in electronics were given a ten-week course and expected to service elaborate electronic equipment. When the number of equipments which they might be called upon to service had more than doubled, the course was lengthened—to twelve weeks!

Instructors. Next to the lack of trained administrators, the lack of trained instructors was probably the greatest weakness in the Navy training system. The majority of instructors were conscientious and hard-working, but they were not qualified teachers. Too often those who became good teachers were transferred and replaced by inexperienced men. Like administrators, instructors should be given special training or selected because they have had the necessary training.

Training Facilities. Classroom and laboratory space, standard equipment, synthetic trainers, and training aids should be planned to meet the needs of a training course. Too often the reverse procedure is followed, i.e., the course is planned to suit the available facilities.

Classroom and laboratory space should be divided so that students can be handled in small manageable groups. For the kind of training usually needed in Navy courses, emphasis should be placed on adequate provisions for laboratory work and operating drill rather than on lecture rooms.

Standard equipment should be provided for training before it is delivered for Service use. This means that training needs must be kept in mind at the time production schedules are established.

Synthetic trainers should be designed to meet the needs of a training course. It is sheer waste to build a trainer, however clever it may be, which does not fit into the training requirements. A good synthetic trainer, in addition to filling definite needs in a training course, should have a number of other features. It should teach skills actually required on real gear; it should provide a reliable scoring system; and it should be reasonably rugged and easy to maintain. Experiments should be conducted with every synthetic trainer to show the value of practice on the trainer relative to practice on real equipment and to no practice at all.

Each particular kind of training aid—instruction book, phonograph recording, movie—should be used only for the purpose to which it is best adapted. Instruction books are excellent for imparting verbal knowledge but they are no substitute for laboratory practice or operating drill. Phonograph recordings are especially valuable for teaching recognition of underwater sounds but they cannot take the place of a good lecturer. Movies can be used to advantage in presenting an overall picture of a tactical situation or in giving a general introduction to a new kind of device but they have little or no value in teaching detailed operating procedures.

The persons responsible for planning of training facilities, design of synthetic trainers, and preparation of training aids should have an intimate knowledge of the training situation for which the work is being done.

1.3.3 The Relation of Training to Research and Development

Close liaison should be maintained between training activities and the laboratories engaged in research and development work. During the course of their experimental work, laboratory groups acquire a great deal of knowledge about how to use and maintain the equipment which they develop. This information should be passed on to training activities. This is of special importance during an emergency when every effort is being made to rush production and get new devices into use as quickly as possible.

The laboratories of Division 6 found it convenient to establish training groups which served as intermediaries between the research and development groups and training activities, thereby relieving the former of duties such as writing instruction books and giving instruction, and providing the latter with maximum assistance. Similar training groups might well be added to the staffs of all laboratories designing and developing equipment for the Navy.

1.3.4 Overall Coordination of Selection and Training

In ASW selection and training, a fair degree of coordination was maintained through COMINCH 10th Fleet and through the Bureau of Naval Personnel. There was, however, too little direct intercourse between the two main sound schools, and between these schools and other ASW activities. Procedures taught to operators and doctrines taught to officers were for long periods lacking in uniformity. Two or more groups often paralleled each other's efforts on projects which could have been conveniently subdivided. Valuable innovations introduced by one activity remained totally unknown to the others.

In submarine selection and training there was no analogue of ASW's 10th Fleet to supervise and coordinate the work of various commands. The lack of overall coordination was, therefore, more noticeable. In parts of the work observed by Division 6 groups there appeared to be little common planning by the activities responsible for training in the Atlantic and in the Pacific, nor by the operational training commands and the basic schools. And there was, seemingly, no agency responsible for establishing uniform standards for entry into the submarine service. For example, at New London men were carefully screened by the Medical Research Department and strict physical and mental requirements were met. At other bases, however, men less well qualified were admitted, evidently because neither the medical nor personnel departments at these bases had been directed to maintain the standards in effect at New London.

To get the most done in the least time it is probably desirable to have numerous units operating almost autonomously. But there is a danger that the units may not only work independently, they may also remain unaware of each other's progress. The mistakes of one group may be repeated unnecessarily by others; or, conceivably, the efforts of one may be in opposition to those of another. Some central agency should act to coordinate and supervise the work of all closely related activities.

Chapter 2

SELECTION OF ANTISUBMARINE WARFARE PERSONNEL

Selection research was undertaken by Division 6 for three classes of antisubmarine warfare [ASW] personnel: sonar operators, sonar maintenance men, and sonar officers. Work on operator selection was begun promptly after acceptance of the selection and training project by NDRC late in 1941; it was continued intermittently during the next two years. A less elaborate program of research on selection of sonar maintenance men was carried on during a period beginning in the summer of 1942 and ending in the spring of 1944. Both of these projects produced selection schemes which were effective in improving the quality of sonar personnel. Considerable research was done on officer selection during 1943 and 1944. Results did not show sufficient promise to warrant the establishment of a selection scheme for sonar officers.

2.1 SONAR OPERATOR SELECTION

The seriousness of antisubmarine warfare at the time of our entry into World War II gave rise to a demand for large numbers of trained sonar operators. The importance of the sonar operator's job and the short time allowed for training made it essential to select men with the aptitudes necessary to their becoming good sonar operators, or at least men with the aptitudes necessary for successful completion of the sonar operator training courses. Fortunately, large groups of men from which to draw were available at naval training centers.

At the first meeting with the Navy of the Committee on Selection and Training, Division 6 was asked to give immediate attention to a selection program. The committee visited the sound schools, where they observed sonar operators during practice attack runs and discussed selection problems with the school staffs. Agreement was reached on the essential features of the operator's job and the aptitudes required for it. Experimental work on selection tests was begun in January 1942. By March, sufficient results had been accumulated to warrant the proposal of an initial selection scheme. The scheme was accepted by the Navy and put into immediate use at the naval training centers. By the end of April, candidates selected by the new methods were arriving at the sound schools.

2.1.1 Initial Operator Selection Scheme

After considering the relevant test materials readily available for administration to large groups, the committee selected the following for experimental use.

1. Otis Test of Mental Ability, Higher Form (20 minutes).
2. Bennett Mechanical Comprehension Test, Form AA.
3. Seashore Measures of Musical Talent, First Edition: Pitch, Intensity, and Tonal Memory Tests.

These tests and a specially constructed personal history questionnaire were given as quickly as possible to 92 students at Key West and 109 at San Diego.

Measures of operator performance available at the two schools were examined as criteria for the selection tests. It was the opinion of the research group that the best single criterion was that obtained at San Diego where two experienced instructors selected the best operators on the basis of performance during attack teacher drills. In the absence of a similar measure for Key West students, the final grade in the operator's course was taken as the criterion for validation. For both experimental groups, students were divided into two categories, "better" and "others." Many different combinations of tests were tried in order to determine the one which would best discriminate between the two groups. The following scheme appeared most promising.

Screen I. Reject any man whose standard score[a] on the Otis Test of Mental Ability is below 35.

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[a] To make scores on all tests comparable, raw scores were converted to standard scores. The mean raw score of a large sample of the population being tested was assigned a standard score of 50. The standard deviation (σ) was taken as 10.

Screen II. Average the standard score on the Bennett Mechanical Comprehension Test with the mean of the standard scores on the three Seashore tests (pitch, tonal memory, and intensity). Reject any man whose average score is below 45.

TABLE 1. Validation of initial selection scheme.*

San Diego (Criterion, attack teacher ratings)	Others	Better	Number
Men who passed both screens	53%	47%	85
Men who failed one or both	100%	0%	24
Key West (Criterion, final grades)			
Men who passed both screens	38%	62%	39
Men who failed one or both	81%	19%	53

* This and following tables may be read as follows: Of 85 men who passed both screens at San Diego, 47% were in the group classed as Better on the basis of their attack teacher grades, 53% in the Others group.

Applied to the experimental groups, the dual screen produced the results[1] shown in Table 1. The differences which may be noted in the two tables are in part due to the different criteria used, but also to the marked difference in quality of men, which is evidenced by the percentages passing both test screens. At San Diego, 78 per cent passed both screens; at Key West, only 42 per cent.

Although these results were based on a limited number of cases, it was felt that the urgent circumstances justified the immediate adoption of the scheme. The Bureau of Personnel concurred, but proposed substituting the Navy General Classification Test [GCT] for the Otis, since the former was already in routine use at the training centers. According to the data then available, the passing score on the Otis was equivalent to a GCT score of 82, so the latter was adopted as the Screen I standard. Later it was found that the corresponding score was actually lower, and the passing score on the GCT was reduced to 76.

2.1.2 Interim Research on Operator Selection

During the period following adoption of the initial selection plan a considerable amount of effort was spent in gathering additional data on its validity, in checking on proper administration of the tests at training centers, and in investigating factors which were not covered in the initial test battery.

Early Follow-up Studies. At San Diego and Key West complete records of selection test scores and school grades were kept for all students, and records of interviews with failing students were added in the course of time. Since some unselected men transferred from sea or not properly screened at the training centers continued to appear in the classes, it was possible to check periodically on the effectiveness of the selection plan. In the fall of 1942, a tabulation at San Diego showed that the two-screen method was discriminating satisfactory from unsatisfactory students (see Table 2). Ninety-four per cent of the men who passed both screens were making satisfactory (above 3.0) grades. Twenty-seven per cent of the men who failed one or both screens were unsatisfactory. It should be noted that many of the men shown in the table as failing one or both screens were borderline cases. The number of unselected or improperly selected men grew rapidly smaller as fewer men were transferred from sea and as administration of selection tests at the training centers improved.

TABLE 2. Follow-up of initial selection scheme.

San Diego (Criterion, final grades)	Unsatisfactory	Satisfactory	Number
Men who passed both screens	6%	94%	257
Men who failed one or both	27%	73%	168

An effort was made in 1942 to obtain records of performance under service conditions. Operating ships were asked to fill out standard report forms for graduates of the operator courses. The number of reports received was not adequate for statistical treatment.

Meanwhile, IBM forms were provided to permit machine scoring of all tests administered at the training centers. Continued checks were made on test reliability and close contact was maintained with the training centers to make sure that tests were administered and scored properly and that only men who passed both screens were assigned to the schools.

Fleet Selection. Throughout most of 1942, the sound schools continued to receive a considerable number of students from the fleet. Perhaps chiefly because ships tended to send the men they could best spare, these fleet transfers were decidedly inferior as students to the men selected at the naval training centers. Authorization was obtained, therefore, to give the selection tests to all men assigned to the school from sources other than the training centers and to refuse admittance to those who were not qualified.

In the meantime, a selection scheme was developed which could be used aboard ship. It differed from that in use at the training centers in two respects: an Inventory of Musical Background was substituted for the Seashore tests, and the Bennett Mechanical Comprehension test was treated as a separate hurdle. A manual of directions for administering the tests was written and was included by BuPers in packages of test materials distributed to ASW ships. About this time, however, the transfer of men from ships directly to the sound schools was stopped and the practicability of the shipboard selection scheme was never determined.

Audiometer Tests. At the New London Submarine Base audiometer tests had been in use prior to 1942; at Key West and San Diego they were quickly instituted for all entering students. The need for such tests was soon confirmed. Although all recruits had been given medical tests involving whispered voice or coin clicks, many cases of serious hearing loss were found and even occasional instances of almost complete deafness in one or both ears.

Extensive studies were made of the relation between hearing loss and various criteria of school achievement. For this purpose audiograms were classified according to the scheme described in Section 4.1.1, and the influence of different levels of hearing loss was systematically examined. In brief, defective hearing was found to be significant for sonar operation if it involved more than a 25-db loss in the 512-2,048 cycle region in one or both ears, or more than 35 db at 4,096 and 8,192 in both ears. Table 3 based upon a study made in San Diego during 1944[2] shows the higher failing rate among men with significant hearing loss.

On several occasions it was suggested that audiometer tests be given at the training stations to eliminate men with significant loss before they reached the schools. This was never done because of the time required to test all candidates. However, use of the tests at the schools was continued, and men with severe hearing loss were dropped.

TABLE 3. Effect of significant hearing loss.

San Diego (Criterion, final grades)	Failed	Passed	Number
Normal hearing or insignificant loss	8%	92%	3,823
Significant hearing loss	15%	85%	180

In order to reduce the labor in giving the tests, an abbreviated procedure was developed at New London (see Section 4.1.1), and some preliminary work was done on a method of group testing. The latter was not completed because of the pressure of more urgent problems.

Tonal Tests. As the importance of doppler discrimination became more widely appreciated, increasing attention was devoted to the auditory discrimination requirements of the initial testing scheme. One weak feature was soon apparent, that is, the practice of averaging scores on the musical aptitude and mechanical comprehension tests was permitting men with inadequate tonal discrimination but high Bennett scores to slip through. This was corrected in the final selection scheme.

It also appeared, from studies conducted at San Diego and New London, that the Seashore tests as they were used in the selection program had a number of defects. The lack of standardized directions on the records, the inadequate numbering of items, and other factors lowered the reliability of the tests. In addition, the intensity test was found to have little validity, the predictive value of pitch and tonal memory being as great as that of all three together.

Efforts were therefore concentrated on developing a single improved test which would measure both pitch discrimination and tonal memory and which would be better adapted, from the standpoint of ease of administration, for use at naval training centers. After several months of experimental work, a Sonar Pitch-Memory Test was produced.[3] The new test was used in the final revision of the operator selection scheme.

Studies of Other Factors. The influence of age and education upon success in the sound school was investigated at San Diego. It was found that men between 20 and 33 years of age were superior on the average to younger and to older men, and that men who had completed 11 years of school were superior to those who had not. These findings were never utilized, because the incoming recruits were predominantly very young men, and an age or schooling requirement would have eliminated an unreasonably large percentage.

Other studies showed that men who had volunteered for sound school obtained better grades than men who had not, but the difference became negligible when the two groups were equated in terms of aptitude test scores. Training centers were instructed by BuPers to select volunteers, and did so whenever the supply of qualified volunteers was sufficient to meet the quota. To increase the number of informed volunteers, a pamphlet describing the sonar operator's job was prepared for distribution to candidates at the training centers.

Because a number of failing students complained of eyestrain, a study of near-vision acuity was carried out at San Diego (the usual Navy test is given only at 20 ft). Scores on the Snellen charts were obtained at both 18 in. and at 20 ft. However, the number of cases failing in the 18-in. test was so small that no clear-cut relation to operator performance could be established.

No adequate tests of motor coordination were developed. Preliminary experiments with a two-hand pursuit meter and with a paper-and-pencil group test involving coordinated response to sound did not give results of sufficient promise to warrant additional study. Men with obvious motor defects were supposedly eliminated at the training center.

2.1.3 Final Operator Selection Scheme

In the fall of 1943, the naval training centers began using the new set of basic classification tests developed by BuPers. With a view to substituting these tests wherever possible for those in the sonar operator selection battery, a new study was made. Scores on the following tests were accumulated for 245 students at San Diego and for 259 at Key West.

1. GCT (NavPers 16502).
2. Reading and Arithmetical Reasoning (NavPers 16512).
3. Mechanical Aptitude (NavPers 16524).
4. Bennett Mechanical Comprehension.
5. Seashore Measures of Musical Talent (tests of time and timbre from new edition).
6. Sonar Pitch-Memory (prepared by Division 6).

Since the students being studied had already been preselected in accordance with the initial selection plan, validation paralleling that of the initial scheme was not possible. However, extensive analysis was made of various test combinations in relation to the criteria available in order to determine which combination gave the best prediction.[4] The following scheme was recommended:

Screen I. Reject any man who makes a standard score of less than 50 on the new GCT or on any two of the other three Navy tests (reading, mechanical aptitude, arithmetical reasoning).

Screen II. Reject any man who makes a standard score of less than 50 (raw score of 80) on the Sonar Pitch-Memory Test.

Examination of these two screens will show that they are somewhat more rigorous than the corresponding parts of the initial selection plan. Screen I (see Table 4) adds an additional hurdle to the simple requirement of a satisfactory GCT. Screen II eliminates the possibility of having a man with poor tonal discrimination slip through on the basis of a good mechanical aptitude score. The Sonar Pitch-Memory Test

TABLE 4. Validation of Screen I, final operator selection scheme.

San Diego and Key West, combined (Criterion, written examination average)

	Failed	Passed	Number
Men who passed Screen I	10%	90%	259
Men who failed Screen I	29%	71%	245

had been found more reliable than the Seashore tests previously used, and was further supported by a correlation of 0.74 with doppler test scores. There is every evidence that the revised scheme would prove to be superior to the initial selection scheme, if both could be validated with a large unselected group.

2.1.4 Discussion

The principal factors measured in both the initial and final selection schemes were general intelligence, mechanical comprehension, and auditory discrimination. Severe hearing loss and gross speech and motor defects were also considered. Of a number of other factors which are undoubtedly important in operation of sonar equipment, several were the subject of preliminary study; others were completely neglected. All would bear investigation in a peacetime research program.

Eye-Ear-Hand Coordination. Marked individual differences were apparent in the ability to make appropriate movements to a complex of visual and auditory signals. Tests which were tried in an attempt to measure aptitude for acquiring this sort of skill were probably oversimplified. Further study should be made to compare the effectiveness of batteries of specific tests and a single job-sample type of test. Research should also include a careful study of the effect of practice. To what extent can the lack of aptitude be overcome by drill?

Temperament. This is perhaps the most important characteristic of all but also the most difficult to measure. It received practically no study in the program here described. Personal history questionnaires were administered but there were no criteria against which to validate the results. Research is needed to develop tests which will select the man who will do his job conscientiously day after day, who will not succumb to monotony, and who will not go to pieces under stress and excitement.

Visual Imagination. A Relative Movement Test, designed primarily to measure ability to visualize relative position and movements of own ship and target, was never applied to sonar operator selection because of the lack of good performance criteria for its validation. This ability is sufficiently important, for operators as well as officers, to justify further study.

Auditory Tests. Besides the pitch-memory test which had face-validity as a measure of ability to make doppler judgments, other tests of auditory discrimination might well be examined. It would seem particularly important to devise a test which measures ability to detect a weak signal in a background of noise.

Unless other auditory tests are used which eliminate the man with gross hearing loss, further attention needs to be given to the development of an audiometer suitable for group testing. Such an instrument would have more general value than merely testing of sonar operators.

Visual Tests. The increased use of the cathode-ray screen to give a picture of the sounds heard adds emphasis to the importance of good near-vision. Visual problems such as reading of dials should be overcome by proper equipment design.

As already noted, the selection researcher must know to what extent and at what rate necessary skills can be acquired by practice. Emphasis should be placed on developing measures of aptitude for the skills which are least susceptible to practice.

The problem of good performance criteria is also fundamental to selection research. Ideally, the best criterion would be an accurate measure of total performance under actual operating conditions. Practically, such a measure is usually impossible to obtain. In the selection of sonar operators, and for that matter in the selection of most specialized personnel in the Navy, the first aim is to select men who can successfully pass a training course. If this prediction of competency is to carry over to performance on the job, a constant effort must be made to make measures of achievement in training courses realistic and reliable.

2.2 SELECTION OF SONAR MAINTENANCE STUDENTS

An elementary sonar maintenance course, ten weeks in length, was given at each of the sound schools. At both schools, the first six weeks were devoted to simple mathematics, rudiments of radio theory, use of tools, and methods of making routine tests with standard test equipment. The final four weeks were spent in practical study of the maintenance and servicing problems commonly encountered aboard ship.

Students for the course were taken from the graduates of the sonar operator course. Since only a small percentage of the operator graduates could be given the additional training, the problem was to select those who were most likely to do well in the maintenance course. Prior to the work on special selection procedures, volunteers with the highest standing in the operator course had been chosen, but this method had not proved completely satisfactory.

The selection of maintenance men differed from that of sonar operators in that there was no formal unified program. Selection methods were developed independently by the resident psychologists at the two schools. However, similar results were achieved.

2.2.1 Research at San Diego

Study of the problem of improving selection methods for maintenance men was begun in the summer of 1942. Scores on standard Navy tests and personal history data, both of which were available in the men's Service records, were correlated with final grades in the maintenance course. The final grade was a composite of marks on weekly written examinations and grades given on shop work, with the examination marks weighted more heavily. The reliability of the written examination average, as measured by odd versus even weeks, was quite high (0.83 for a group of seven classes).

Initial Selection Plan. The outcome of a brief preliminary study was the adoption of a procedure which selected men on the basis of the following four measures.

1. GCT (old edition).
2. Arithmetic Test (old edition).
3. Number of units of education in science and mathematics. (One-half year in college was considered equal to one year in high school.)
4. Average grade on two examinations given in the sonar operator course.

All scores were converted to standard scores. A composite score was determined for each man by averaging his standard scores for the four measures. Correlations between the composite scores and final grades in the maintenance course ranged from 0.65 to 0.88 for a series of classes, whereas operator course grades alone gave a maximum correlation of only 0.53.

More concrete evidence of the effectiveness of the plan is shown by the results in Table 5. A minimum passing score of 55 gave a sharp division between satisfactory and unsatisfactory students. Eighty-one per cent of the students with scores of 55 or better received satisfactory grades in the course. Seventy-seven per cent of students with scores less than 55 received unsatisfactory grades.

TABLE 5. Validation of initial maintenance selection.

San Diego	*(Criterion, final grades)* Unsatisfactory	Satisfactory	Number
Average standard score of 55 or better	19%	81%	36
Average standard score of less than 55	77%	23%	30

Revised Plan. In the fall of 1943, the basic battery of Navy tests given at the training stations was revised. This necessitated a slight change in the scheme used for selecting maintenance students, the new tests being substituted for those formerly used. The new scheme included:

1. GCT (NavPers 16524).
2. Arithmetical Reasoning Test (NavPers 16512).
3. Reading Test (NavPers 16524).
4. Bennett Mechanical Comprehension Test.
5. Number of units of education in science and mathematics.
6. Average grade on two operator examinations.

As before, those graduates of the operator course were selected who had the highest composite scores determined by averaging the standard scores for the six selection measures.

During the spring of 1944, correlations of composite scores against final maintenance course grades were made for a total of 140 students. Although these students had already been preselected, a small positive correlation of 0.41 was obtained. Application of standard statistical procedures indicated that a correlation of about 0.70 would have been obtained with an unselected group of operator graduates.

2.2.2 Research at Key West

The first work on selection of sonar maintenance men at Key West was begun in July 1942. As at San Diego, scores on standard Navy tests and personal history data were utilized. Different combinations of test scores and scores arbitrarily assigned to such factors as education, experience, and interest were correlated with final grades in the maintenance course.

Initial Selection Plan. As a result of preliminary studies, a selection scheme was evolved and put into use in the fall of 1942.[5] It involved three successive hurdles.

Screen I. Select only those men who are volunteers and who are high school graduates.

Screen II. Select the men with highest scores on GCT, Bennett Mechanical Comprehension Test, and Navy Arithmetical Reasoning Test. Also consider such factors as interest in radio and training in electronics.

Screen III. Select men with highest standing in sonar operator course.

The high school graduate qualification of Screen I had to be modified at times in order to fill the course quota. No specific weights were assigned to the several factors listed in Screen II. Tests were considered in the order listed, GCT as most important, and so on. Screen III was included primarily as a means of raising morale in the operator course, admittance to maintenance training being highly desired by the majority of the operator students.

The effectiveness of this initial selection scheme is illustrated by the figures[6] in Table 6. These figures were compiled for a number of classes entering the course after the adoption of the selection plan. For various reasons, however, a number of men had been admitted to these classes who did not meet the selection standards.

TABLE 6. Validation of initial maintenance selection.

Key West (Criterion, final grades)	Unsatisfactory	Satisfactory	Number
Men meeting selection standards	8%	92%	186
Men below selection standards	22%	78%	18

Revised Plan. When the Navy basic test battery was revised by BuPers in the fall of 1943, Screen II of the initial plan could no longer be employed. It was decided to try out a new test, the Iowa Engineering and Physical Science Aptitude Test. This test included six parts: (1) mathematical comprehension, (2) ability to formulate solutions, (3) scientific comprehension, (4) arithmetical reasoning, (5) verbal comprehension, (6) mechanical comprehension.

Analysis based on 101 students showed that the first and fourth parts did not contribute to prediction of success in the course. For the remaining four parts, a multiple correlation of 0.61 with final course grades was obtained. This multiple would have been higher but for the exclusion of 20 failures for whom no final grades were available. Using a weighted composite score, clean-cut discrimination was obtained between satisfactory and unsatisfactory students. Results for a total of 121 cases are shown in Table 7.

TABLE 7. Validation of Iowa Engineering and Physical Science Aptitude Test.

Key West (Criterion, final grades in maintenance course)	Unsatisfactory	Satisfactory	Number
Men passing Iowa test	23%	77%	86
Men failing Iowa test	71%	29%	35

Thereafter, the scores on the Iowa test were used as Screen II; Screens I and III remained the same.

2.2.3 Discussion

The available evidence indicates that a fair degree of success was achieved in the selection of maintenance students. Whether the selection methods picked men who were most likely to become good shipboard maintenance men is not known. The criteria were heavily weighted with written examinations, and a major portion of the courses consisted of theory. In general, grades on written examinations and knowledge of theory have not been shown to be highly correlated with actual servicing ability. A selection method which predicts the former successfully may have little value for the latter.

At various times it was suggested that either the nature or the length of the maintenance course should be changed. Industrial concerns have had success in teaching relatively short maintenance courses which concentrate on standardized procedures with a minimum of theory. The students entering the maintenance courses had little or no background in electronics. The attempt to teach them basic theory and routine maintenance procedures all in ten weeks did not seem wise. However, the course length had been established, and the Navy was committed to a policy of teaching maintenance men to be independent of the sort of fixed routine procedures which are usual in industry.

2.3 SONAR OFFICER SELECTION

By the spring of 1943 the importance of the sonar officer's job had increased to the point where the sound schools at Key West and San Diego felt that students for their sonar officer courses should be specially selected. Most of these officers were being assigned directly from ships, although part of the Key West students were sent from the Submarine Chaser Training Center [SCTC], Miami, and the Antisubmarine Warfare Instructor School, Boston.

As a temporary measure, BuPers directed officer indoctrination centers to use the sonar operator selection scheme in choosing officers to be sent to sonar school. In May 1943, Division 6 was asked to undertake a research program on sonar officer selection. Work was continued until June 1944. Because a great many unforeseen difficulties were encountered, no conclusive results were obtained.

2.3.1 Preliminary Research

A battery of 13 tests, chosen by the Committee on Selection and Training, was administered to four classes at Key West and six at San Diego, a total of 148 officers. Test scores were correlated with final grades, which were based upon written examinations and ratings of performance during attack teacher and training ship exercises.

The correlations were low. The best scheme gave a multiple correlation of only 0.49. It made use of these five tests.

1. Mathematical Comprehension and Interpretation Test (devised by a member of the committee).
2. Bennett Mechanical Comprehension Test.
3. Seashore Measures of Musical Talent, old edition (average of standard scores for pitch and tonal memory).
4. Officer Qualification Test.
5. Army Air Force Aptitude Test III.

To check these findings, similar data were accumulated for an additional 83 officers. For 31 cases at San Diego, the multiple correlation dropped to 0.43; for 52 cases at Key West, almost to zero.[7]

Certain causes for the failure were clearly apparent. The test battery had required nine hours, which had to be taken from the small amount of free time which students were allowed. Some of the tests included items which appeared nonsensical to the students. The grades used as criteria were unreliable and variable in standard of severity from class to class. Finally, just before the research started, the system of obtaining sonar officer students was changed so that the majority were drawn from SCTC, Miami. Since SCTC chose these officers on the basis of operator selection tests, interest, and other factors judged as relevant, the groups used in the validation study were not typical of the general officer population.

2.3.2 Final Officer Research

A second attempt to develop a suitable sonar officer selection scheme was made in the spring of 1944. By this time better criteria had become available. Objective-type written examinations of established reliability and realistic and reliable measures of performance on the sound range recorder, a most important aspect of the sonar officer's job, were in use at both schools. These two factors were combined with an instructor's overall rating to give a *composite criterion*. Scores on a recorder doppler test were used as an independent criterion.

The test battery was also altered. Army Air Forces tests of surface development and mechanical relations were revised into a more suitable form. A new relative movement test was constructed as a measure of ability to visualize relative position and relative movement of ships. (See page 18 for detailed description.) The complete experimental battery, including these tests and some of those used in earlier officer and operator studies, is listed below.

1. Officer Qualification Test.
2. Relative Movement Test.
3. Mathematical Comprehension and Interpretation Test.
4. Bennett Mechanical Comprehension Test.
5. Mechanical Relations Test (Air Force VI).
6. Surface Development Test (Air Force III).
7. Sonar Pitch-Memory Test.
8. Seashore Time and Timbre Tests.

The battery of tests was administered to 104 officers at Key West and to 99 at San Diego.[8] For the Key West group, the highest correlation between any single test and the composite criterion was 0.19. Therefore, no multiple correlations were determined. For the San Diego group, a weighted average of the Relative Movement and Bennett Mechanical Comprehension correlated 0.50 with the composite criterion. The Sonar Pitch-Memory Test correlated 0.72 with scores on the doppler tests.

The difference in results for the two schools was probably due mainly to the difference in grading systems used. It was the opinion of the research group that the Key West grades were not sufficiently reliable to be useful for a validation study.

A four-hurdle scheme using the tests which appeared most promising in final work at San Diego was suggested to BuPers as a possible stopgap measure. The four hurdles were these:

1. Informed volunteer status.
2. Relative Movement Test, raw score of 20 or better.
3. Bennett Mechanical Comprehension Test (15 min), raw score of 40 or better.
4. Sonar Pitch-Memory Test, raw score of 80 or better.

Since the demand for sonar officers was by then decreasing and since a very high percentage of the officers who could be assigned to sonar training would have been eliminated by the four-hurdle scheme, it was not adopted.

Continuation of the research program in the hope of obtaining a better selection scheme did not appear desirable for a number of reasons. Under existing conditions, careful administration of a battery of tests was extremely difficult and the lack of meaningful and reliable criteria could not be corrected readily. Furthermore, the research group was needed to assist in the more urgent selection and training work for submarine personnel.

About the only positive outcome of the officer selection research was the development of the relative movement test.[9] This appeared to have promise as a measure of ability to visualize position and movement of objects in space. It was used by BuPers in further selection research.

THE SONAR PITCH-MEMORY TEST

The Sonar Pitch-Memory Test consists of 100 items, each comprising two very short tones three seconds apart. Subjects are required to judge whether the second tone is higher or lower in pitch than the first. The frequency of the first tone is one of three values, varied in random order, 775, 800, or 825 c. In each item the second tone differs from the first by from 5 to 35 c. The number of items involving each degree of difference are: 20 items each at 5, 10, 15, and 20 c; 10 items at 25 c; and 5 items each at 30 and 35 c. These proportions were based on observed difficulty levels. Announcements of the serial numbers of test items and directions for taking the test are given on the recordings.

In standardizing the test, the following data were obtained concerning score distributions and reliability.

Group	Number	Mean	Standard Deviation	Reliability
Unselected recruits	609	74.2	13.9	0.89 (split-half)
Recruits over 50 GCT	224	80.2	10.6	0.91 (split-half)
Selected sonar students	162	88.2	6.7	0.84 (test-retest)

The test is now distributed by the Bureau of Naval Personnel. Records are listed as NavPers 11750 RA and RB and 11751 RA and RB.

THE RELATIVE MOVEMENT TEST

The Relative Movement Test is a test of ability to visualize navigational relationships. It contains 40 questions which must be answered within 30 minutes without the use of sketches or diagrams. Typical items are

> Ship *A* is steering north at 10 knots. Ship *B* is 10 miles west and steering northeast at 10 knots. Ship *B* will
> (a) collide with *A* (b) pass ahead of *A* (c) pass astern of *A*.
> Ship *A* is headed east at 10 knots when ship *B* leaves the same place headed south at 20 knots. After a half-hour, ship *B* changes course and heads east. After another half-hour, what is the direction of *B* from *A*?
> (a) SW (b) S (c) SE (d) E.

Scores obtained from 102 officer students yielded a mean of 21.67 items correct, with a range from 4 to 40 and a standard deviation of 6.11. Estimation of reliability by the Kuder-Richardson method gave a value of 0.73. Some of the correlations found with other tests were

Officer Qualification Test	0.26
Sonar Pitch-Memory Test	0.28
Bennett Mechanical Comprehension Test (BB)	0.41

The first form of the Relative Movement Test was prepared at Key West in July 1943. It was revised and improved at San Diego in January 1944. The revised form, then designated as Form B, is the one described above. A further version containing 45 items was issued later by the Bureau of Navy Personnel as part of the CIC Aptitude Test (NavPers 16980) and also as a separate test (NavPers 16616).

Chapter 3

TRAINING OF ANTISUBMARINE WARFARE PERSONNEL

3.1 INTRODUCTION

In the fall of 1941, sonar training on a limited scale was being conducted at the West Coast Sound School [WCSS], San Diego, and at the Fleet Sound School [FSS], Key West. The combined monthly output of the schools was approximately 100 operators, 30 maintenance men, and 20 officers.

Then came our entry into the war and the sudden need for vast expansion of the antisubmarine warfare [ASW] training program. The number of sonar students was tripled but the schools had neither the facilities nor the personnel to train men at the rate required. In fact, many of their instructors and some of their training ships had been withdrawn for active duty.

As a result, students in the greatly enlarged classes spent most of their time listening to lectures, studying the meager instruction books, or standing by waiting for a turn on the few pieces of training equipment which were available. Throughout his entire course, each operator received perhaps an hour or less of actual practice in operating standard gear. Maintenance students likewise had little opportunity to work with real equipment. Officers were given about the same training as the enlisted operators. A few were also put through an intensive matériel course, with little consideration to the adequacy of their background knowledge or experience.

There were other problems besides those arising from sudden expansion. Operating procedures and antisubmarine attack doctrine were imperfectly developed and completely unstandardized. Few officers had received any training in conning a sonar attack. The morale of men assigned to schools for sonar instruction was low, because there was no sonar rating and therefore no chance for advancement through specialization in this field. Sonar students were frequently chosen from those least skilled and least ambitious.

Such was the situation when NDRC was asked to assist in development of training methods. Although the major concern at the start was the development of selection methods, the division also gave immediate attention to the problem of training sonar operators and maintenance men.

Early in 1942 a group was organized at the University of California Division of War Research [UCDWR] laboratory to design synthetic trainers. Within a few months, primary and advanced bearing teachers had been developed and preliminary models furnished to the schools while additional units were being manufactured in quantity. Shortly thereafter practice targets were developed to aid in underway training.

By the summer of 1942, training groups were in residence at both sound schools and were working with the instructional staffs to improve the training courses. Qualified civilian instructors had been recruited to supplement Navy personnel in staffing the maintenance schools. Meanwhile, sonar ratings had been established by the Navy, with a resulting improvement in the morale of the enlisted students.

By the end of 1942 the sound schools were graduating approximately 500 sonar operators a month. Yet the supply of synthetic trainers and the facilities for the sea-training phase had increased to such an extent that every student received approximately fifteen times as much operating practice as at the beginning of the year. Attack doctrines were being standardized, and the need for special sonar officer training was becoming increasingly apparent.

During 1943 new members were added to the groups stationed at the sound schools and the scope of their work was greatly expanded. More attention was given to basic educational procedures, such as course planning, preparation of instructional material, improvement of teaching techniques, and measurement of student proficiency. Synthetic trainers became available to the schools in quantity, making possible a large increase in the amount of time which could be spent in operating drill. Production units of standard sonar equipment also became more plentiful for use in both operator and matériel courses.

The work of the synthetic trainer group at UCDWR was supplemented by similar groups at other division laboratories. The pressure to produce devices in a hurry had been reduced sufficiently to permit more careful planning and design. Experience had shown the need for group training devices. With the development of the range recorder teacher [QFL], and the experiments in monitoring a number of advanced bearing teachers from a central console, a new trend toward group trainers was definitely established.

To a limited extent, Division 6 assistance was extended during 1943 to ASW training activities other than the two sound schools. Men were assigned to COTCLant and to COMINCH 10th Fleet to advise on matters of training and to maintain liaison between these activities and the division laboratories and training groups.

Still another extension of training activities arose from the need for setting up training programs for new ASW devices developed by the division laboratories. During 1943 groups were formed at the laboratories specifically to assist Navy training activities in teaching men to use and service this new equipment.

By 1944 a shift in emphasis from antisubmarine to prosubmarine training was taking place, but considerable ASW work continued. The training groups at the sound schools concentrated mainly on the introduction of new synthetic trainers and upon refinements in the methods of measuring student performance. Liaison work with refresher activities of the Atlantic and Pacific training commands was extended during the early part of the year. New synthetic trainers for group training were developed, notably the *echo recognition group trainer* [ERGT] and the group operator trainer. A number of training programs for laboratory developments such as the *bearing deviation indicator* [BDI], the *magnetic airborne detector* [MAD], and the *expendable radio sono buoy* [ERSB] were under way.

Early in 1944, in collaboration with BuShips, a project (NS-252) was set up under UCDWR to write instruction books on installation and maintenance of all standard sonar equipments. A staff of some 50 persons including technical writers, editors, engineers, artists, and clerical assistants was formed. Several manuals were completed in 1944, the remainder in 1945.

By 1945 ASW training was low in priority of importance, and the efforts of the Division 6 training groups were being devoted almost entirely to submarine training.

So much for the general historical perspective. For a more detailed picture of the individual phases of ASW training, it is convenient to consider the work under three headings: (1) assistance to the Navy sound schools; (2) liaison; (3) training programs in connection with laboratory developments.

3.2 ASSISTANCE TO THE NAVY SOUND SCHOOLS

As previously mentioned, training groups assigned to WCSS and to FSS worked closely with the instructional staffs at these schools to improve the training programs for sonar operators, maintenance men, and officers. Assistance given included (1) curriculum revision, (2) achievement testing, (3) instructor training, (4) preparation of training aids, and (5) construction of synthetic trainers. In some instances, members of the training group served as instructors for limited periods.

3.2.1 Curriculum Revision

As soon as training group personnel became familiar with the jobs of sonar operation and maintenance and with the procedures of the schools, they were able to suggest valuable changes or additions to the course curricula. Further changes became necessary as experience developed. Schedules were revised to allow for drill periods on new synthetic trainers, and provisions were made for training on new ASW devices. In some cases, results on achievement tests uncovered deficiencies which could be corrected only by a redistribution of time.

At Key West, the training group aided in making complete revisions of curricula for operators, maintenance men, and officers. This work was started in the summer of 1942 and continued over the next two years. At San Diego, the training group never undertook a complete revamping of course curricula, but through day-to-day contacts it exercised considerable influence on the changes which were made. At both schools, training group personnel took a particularly active part in introducing instruction on new equipment and in developing programs for synthetic trainers.

3.2.2 Achievement Testing

At the start, the only measures of achievement at the sound schools were marks on unstandardized written quizzes and rather perfunctory ratings of performance during attack teacher drills ashore and simulated attack runs at sea. The inadequacy of these measures was a serious handicap in both selection and training. In selection, good measures of performance were needed as criteria for selection tests; in training, for evaluating the effectiveness of various aspects of the training program. A constant effort was therefore made to improve methods of measuring both technical knowledge and operating skill.

1. Own ship is on course 315. Contact is made with a target at 015 True. Own ship then changes course to 045. The target's relative bearing will shift to
   1 060
   2 270
   3 285
   4 330
2. A range of 2,000 yards is reported as
   1 Two oh double oh
   2 two thousand
   3 Two zero zero zero
   4 Two oh oh oh
3. During search the filters should be set on
   1 Broad—Peak
   2 Broad—Flat
   3 Sharp—Band
   4 Sharp—Peak

FIGURE 1. Sample questions from an objective-type operator examination.

Written Examinations. Beginning in 1942, objective written examinations (see Figure 1) were substituted for the nonstandardized essay-type quizzes at both sound schools. During the next two years the quality of these standard examinations was constantly improved. Continual review kept the subject matter in step with new developments in equipment, procedures, and tactics. Item analysis was used to eliminate ambiguous and nondiscriminating questions. Two or more equivalent forms were developed for each examination.

Unfortunately, the value of a written examination as a criterion of achievement for a sonar operator, maintenance man, or officer is somewhat limited. Knowing all the answers is no proof that a man possesses the skills necessary for the job. For this reason, written examination grades were finally dropped in computing students' final grades at Key West, and were reduced to a nominal third of the total at San Diego. Nevertheless, written examinations continued to be of value in showing what technical knowledge the students were acquiring from the lecture sessions and study of manuals.

Measures of Performance. It is a routine task to develop good standardized written examinations which adequately test technical knowledge. It is much more difficult to find satisfactory measures of operating skill, especially in such a complex performance as that of the sonar operator. Yet this matter of performance is fundamental in validating selection methods or in determining the effectiveness of training.

There were two situations in the sound schools where attempts to measure performance could be made: (1) practice attack runs at sea and (2) drills on synthetic trainers ashore.

Repeated efforts were made to develop reliable measures of performance during the sea phase of training, but with little success, because of the impossibility of obtaining uniform conditions for testing. Especially when sound conditions were bad, contacts were made at such short range that normal operations were impossible. Even with good sound conditions, practice attack runs could not be standardized.

On the attack teacher, standardized runs could be used and students observed under comparable conditions. A number of simple direct scoring methods were tried. For example, at Key West a scheme of counting the total number of items of correct information was given a thorough tryout. Although this produced reasonably reliable scores, the method was dropped because it was considered too artificial. The best operator is not the one who pours out the greatest flood of information, but the one who makes the most skillful use of his equipment to produce the information needed for a successful attack.

On other synthetic trainers, simple direct scores were more meaningful. The average firing time error on the range recorder teacher, for instance, measures the final outcome of a complex performance. As an indication of ability in making sound discriminations, the highly reliable scores obtained on the standard doppler tests and later on the echo recognition group trainer are related to a significant part of the operator's task.

The use of scores such as these in validating selection procedures has been described in Chapter 2. They were also useful in evaluating the results of training. For example, the extent to which students were benefiting from specialized doppler drills was measured by the doppler tests. Similarly, the minimum time needed to reach a reasonable degree of proficiency and the value of continued training beyond the minimum could be determined by use of QFL firing time tests (see Figure 2).

Where there were no means of obtaining direct scores to indicate proficiency, checking systems were devised. These usually contained items of two different types: (1) checkoff items of an all-or-none nature (e.g., Operator throws heterodyne switch to ON position: Yes——— No———); and (2) rating scale items where the instructor or checker was required to judge the degree of goodness of performance (e.g., Operator reports doppler: promptly and correctly———, correctly but with delay———, incorrectly———, not at all———).

During 1942 and 1943, a checking system was developed for use in attack teacher drills at Key West. Later a similar system was employed at San Diego. At both schools, checking systems were used to grade performance on the advanced bearing teachers and the group operator trainers. In some instances, weights were assigned to each item checked and a total numerical score determined. Scores determined in such a manner for attack teacher drills at Key West were found to have a reliability as high as 0.82 when grading was carried out by a trained team.

3.2.3 Instructor Training

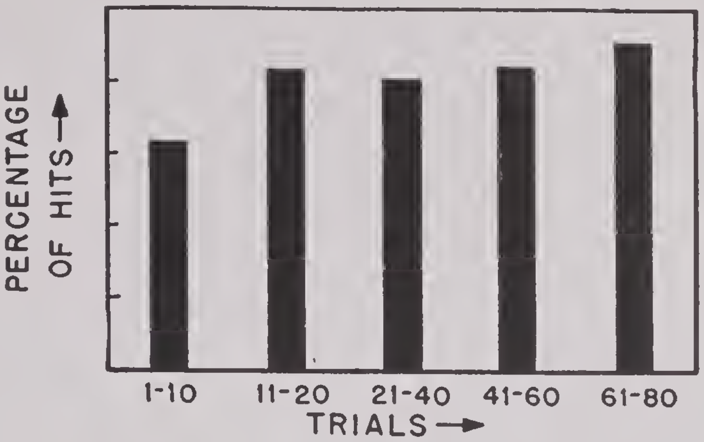
Relatively little was attempted at the two sound schools in the way of formal classes on the subject of how to teach. Much was accomplished indirectly. Navy instructors frequently came to members of the training group for advice, and meetings to discuss new devices and new methods gave an opportunity to bring out general principles of effective teaching.

At San Diego during 1944, phonograph recordings were made of the lectures of all instructors. Training group personnel went over the recordings with each instructor individually and discussed means of improving both the content of the lectures and the manner of presentation.

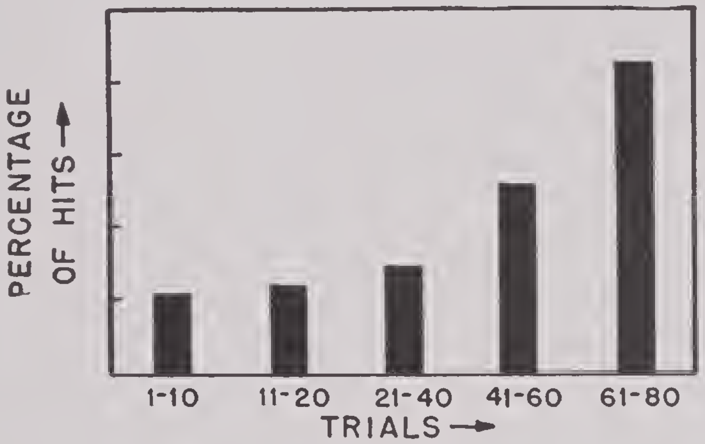
Much of the instructor training centered around the introduction of new laboratory developments and new training devices. Specialists from the laboratories frequently conducted brief training courses on new developments for the benefit of instructors. With new training devices, the original programs of instruction were usually developed by members of the training group; Navy instructors were then trained to take over. For example, the program of range recorder teacher drills at San Diego was worked out experimentally during late 1943 and early 1944 by training group personnel,[10] and in the spring of 1944 a similar method of development was used with the echo recognition group trainer. In each case, Navy instructors worked with the civilian instructors for several weeks before assuming full responsibility for conduct of the drills.

3.2.4 Preparation of Training Aids

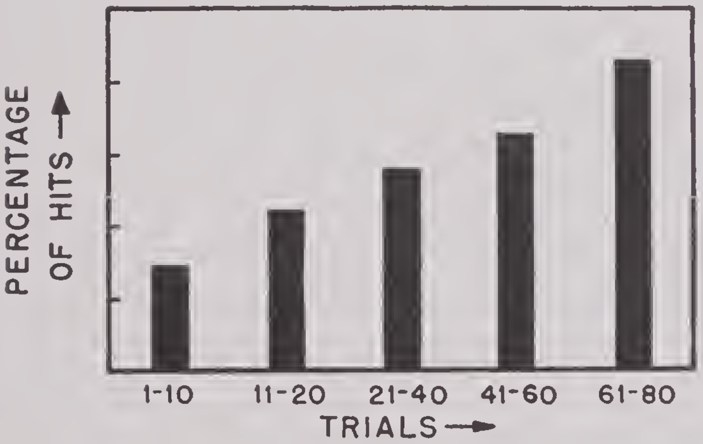
Instructional materials were needed for many phases of the training work. From the summer



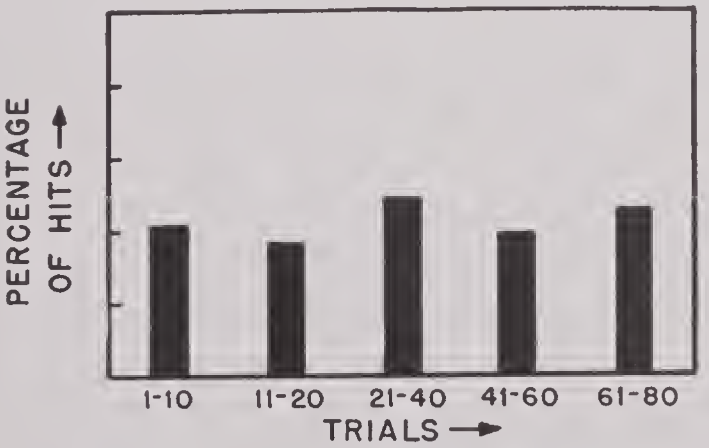
Type 1. Problems of this kind are quickly mastered. There is no point in long-continued training.



Type 2. Improvement is very slow at first but finally takes place suddenly. Training should be continued long enough to take advantage of the marked increase in learning.



Type 3. Improvement is continuous throughout entire period. Results achieved are directly proportional to length of training.



Type 4. There is no apparent improvement. Either practice time must be extended or more effective drills must be designed.

FIGURE 2. Effects of training on results in four different types of QFL firing drill exercises.

of 1942 on, considerable time and effort went into the production of instruction books, phonograph recordings, slides and films, and miscellaneous classroom demonstration devices.

In preparing instruction books, an attempt was made to get away from the dull, drab, disorganized texts which were in use at the start of the war. In books for operators, useless technical information was eliminated; in books for maintenance men, such information was made as simple and clear as possible. Illustrations were used for functional, not decorative, purposes.

The majority of instruction books prepared by Division 6 groups were for use with sonar equipment or synthetic trainers developed by the division laboratories. In a number of instances, however, texts of a more general nature were written. Assistance was given to WCSS in the preparation of a series of books on maintenance of surface craft sonar equipment. The first book, *Notes on Servicing Radio and Sound Equipment,* was distributed by BuShips in 1942. It was a revision and amplification of the maintenance instructions in use at the San Diego school. A more extensive *Sonar Material Handbook,* covering types of sound equipment, servicing procedures, and routine maintenance and adjustments, was issued in February 1943 and similarly distributed. Later a monthly *Sonar Bulletin* giving information on new developments, and a *Sonar History Record* (later called *Sonar Equipment Log*) were issued. Meanwhile, a massive 1,066-page looseleaf *Sonar Maintenance Handbook* (see Figure 3) was in process of preparation. It was issued in August 1944 and distributed by BuShips. This handbook covered maintenance and repair of all types of sonar equipment in use at the time. Some 500 additional pages on new developments were issued at a later date.

In the spring of 1944, NDRC undertook for BuShips under its UCDWR contract a project to prepare a series of maintenance manuals for all types of sonar equipment. A staff of some 50 technical writers, editors, artists, and clerical assistants was formed in New York City. Several Navy officers were also assigned to the project by BuShips. Of the thirteen manuals planned, the first, a *Sonar Equipment Log,* was issued in May 1944 and was followed by others at intervals during 1944 and early 1945. After February 1945 the work was continued under a BuShips-UCDWR contract until all the projected manuals were published.

As part of a special training program for range recorder operators, members of the Division 6 training group collaborated with AsDevLant, Surface Division, in the preparation, first, of a preliminary instruction book, *Interpretation of Sound Range Recorder Traces* and later of a final book, *Operation of the Sound Range Recorder* (see Figure 5). The latter was published and distributed by COMINCH to all ASW ships and activities.

When the Division 6 groups first became active in ASW training, a large number of miscellaneous recordings of underwater sounds were on hand at the sound schools. Few of these were of any value since the material on the recordings was not properly identified. Incomplete information was given as to the source of sound examples, the kind of equipment used in receiving the sound, the range of sound source from the receiver, and all the other details which could make the recordings useful in teaching sonar operators. Furthermore, the recordings had not been planned with the idea of using them for training purposes.

Since phonograph recordings could be effective training aids in the field of sonar, the recording facilities which had been built up at the division laboratories for experimental work were used to make training recordings. From these a series of five albums of ASW recordings was prepared for distribution by BuPers. The first three albums, issued in 1943, contained (1) examples and explanation of sounds heard during echo ranging, (2) exercises to teach search and cut-on procedures and echo recognition, and (3) examples of practice attack runs on a submarine. The fourth and fifth albums, issued early in 1944, contained a set of drill recordings to teach recognition of doppler, and examples of sounds produced by torpedoes and by the noisemakers used to attract acoustic torpedoes. All recordings were accurately labeled, and each album contained an index list as well as a pamphlet of directions for the instructor (see Figure 6). The ASW training recordings

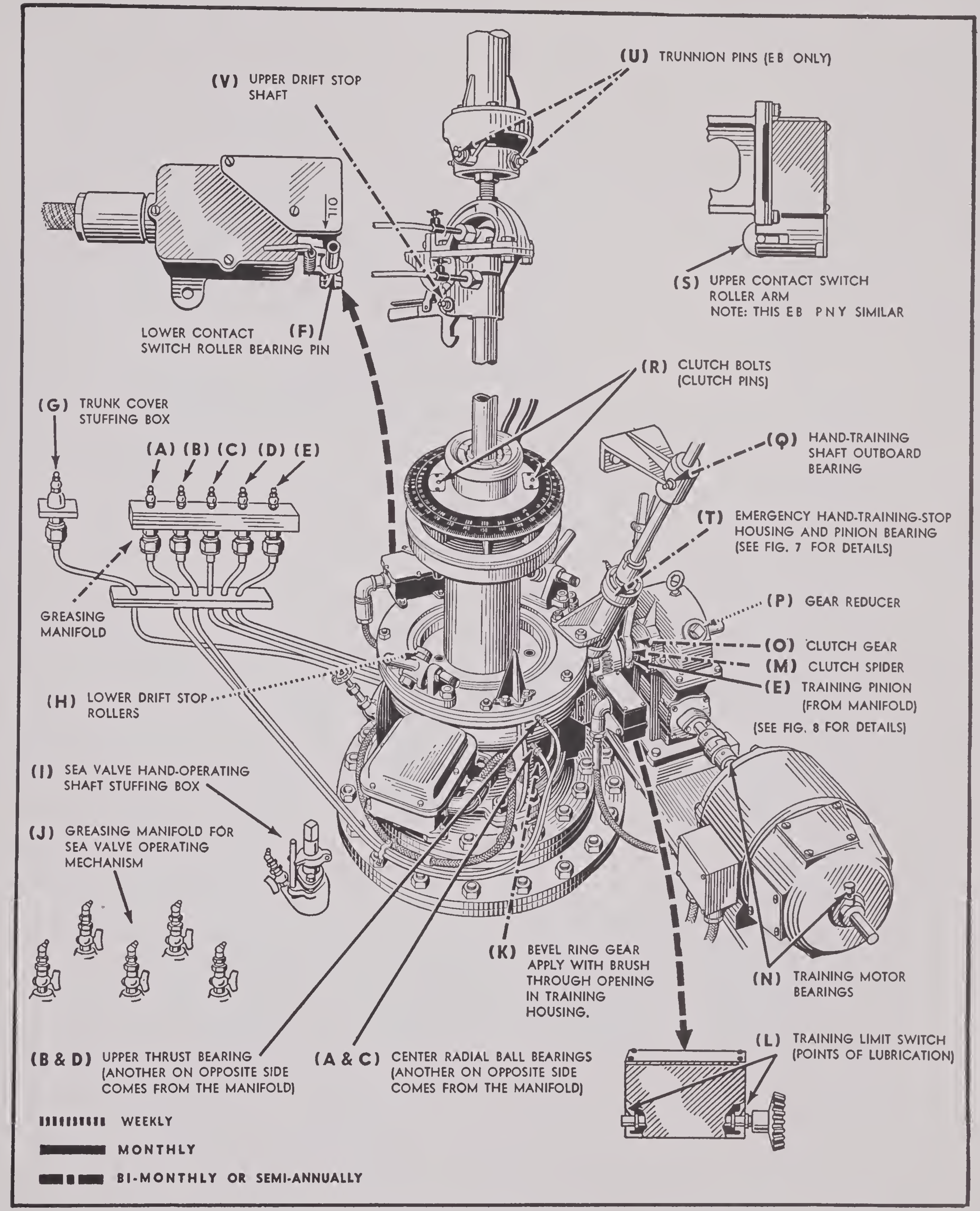

(U) TRUNNION PINS (E B ONLY)
(V) UPPER DRIFT STOP SHAFT
OIL
(S) UPPER CONTACT SWITCH ROLLER ARM
NOTE: THIS E B P N Y SIMILAR
LOWER CONTACT SWITCH ROLLER BEARING PIN (F)
(R) CLUTCH BOLTS (CLUTCH PINS)
(G) TRUNK COVER STUFFING BOX
(A) (B) (C) (D) (E)
(Q) HAND-TRAINING SHAFT OUTBOARD BEARING
(T) EMERGENCY HAND-TRAINING-STOP HOUSING AND PINION BEARING (SEE FIG. 7 FOR DETAILS)
(P) GEAR REDUCER
GREASING MANIFOLD
(O) CLUTCH GEAR
(M) CLUTCH SPIDER
(E) TRAINING PINION (FROM MANIFOLD)
(SEE FIG. 8 FOR DETAILS)
(H) LOWER DRIFT STOP ROLLERS
(I) SEA VALVE HAND-OPERATING SHAFT STUFFING BOX
(J) GREASING MANIFOLD FOR SEA VALVE OPERATING MECHANISM
(K) BEVEL RING GEAR APPLY WITH BRUSH THROUGH OPENING IN TRAINING HOUSING.
(N) TRAINING MOTOR BEARINGS
(L) TRAINING LIMIT SWITCH (POINTS OF LUBRICATION)
(B & D) UPPER THRUST BEARING (ANOTHER ON OPPOSITE SIDE COMES FROM THE MANIFOLD)
(A & C) CENTER RADIAL BALL BEARINGS (ANOTHER ON OPPOSITE SIDE COMES FROM THE MANIFOLD)
WEEKLY
MONTHLY
BI-MONTHLY OR SEMI-ANNUALLY

FIGURE 3. Page from *Sonar Maintenance Handbook.*

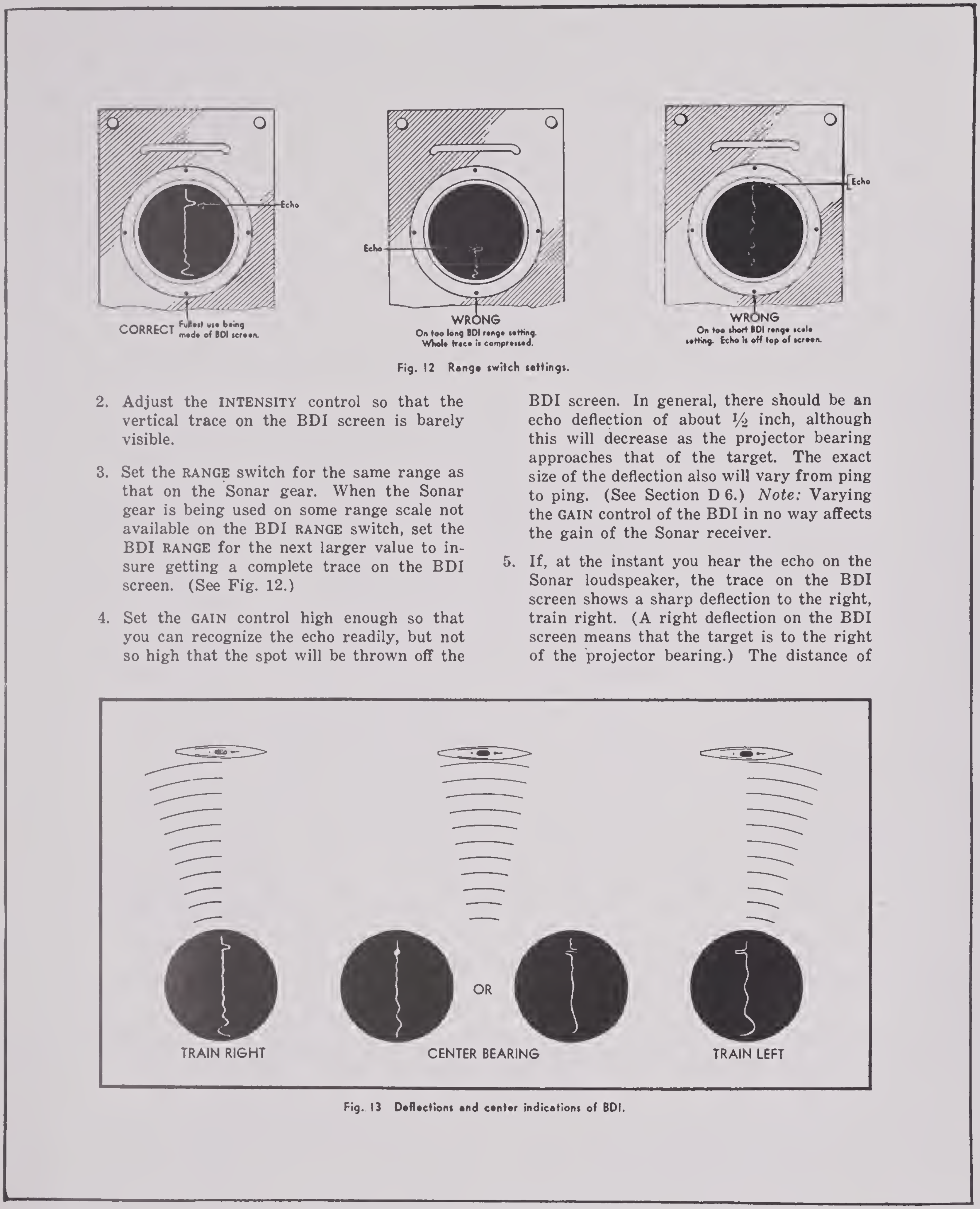

Echo
CORRECT Fullest use being made of BDI screen.
Echo
WRONG On too long BDI range setting. Whole trace is compressed.
Echo
WRONG On too short BDI range scale setting. Echo is off top of screen.

Fig. 12 Range switch settings.

2. Adjust the INTENSITY control so that the vertical trace on the BDI screen is barely visible.

3. Set the RANGE switch for the same range as that on the Sonar gear. When the Sonar gear is being used on some range scale not available on the BDI RANGE switch, set the BDI RANGE for the next larger value to insure getting a complete trace on the BDI screen. (See Fig. 12.)

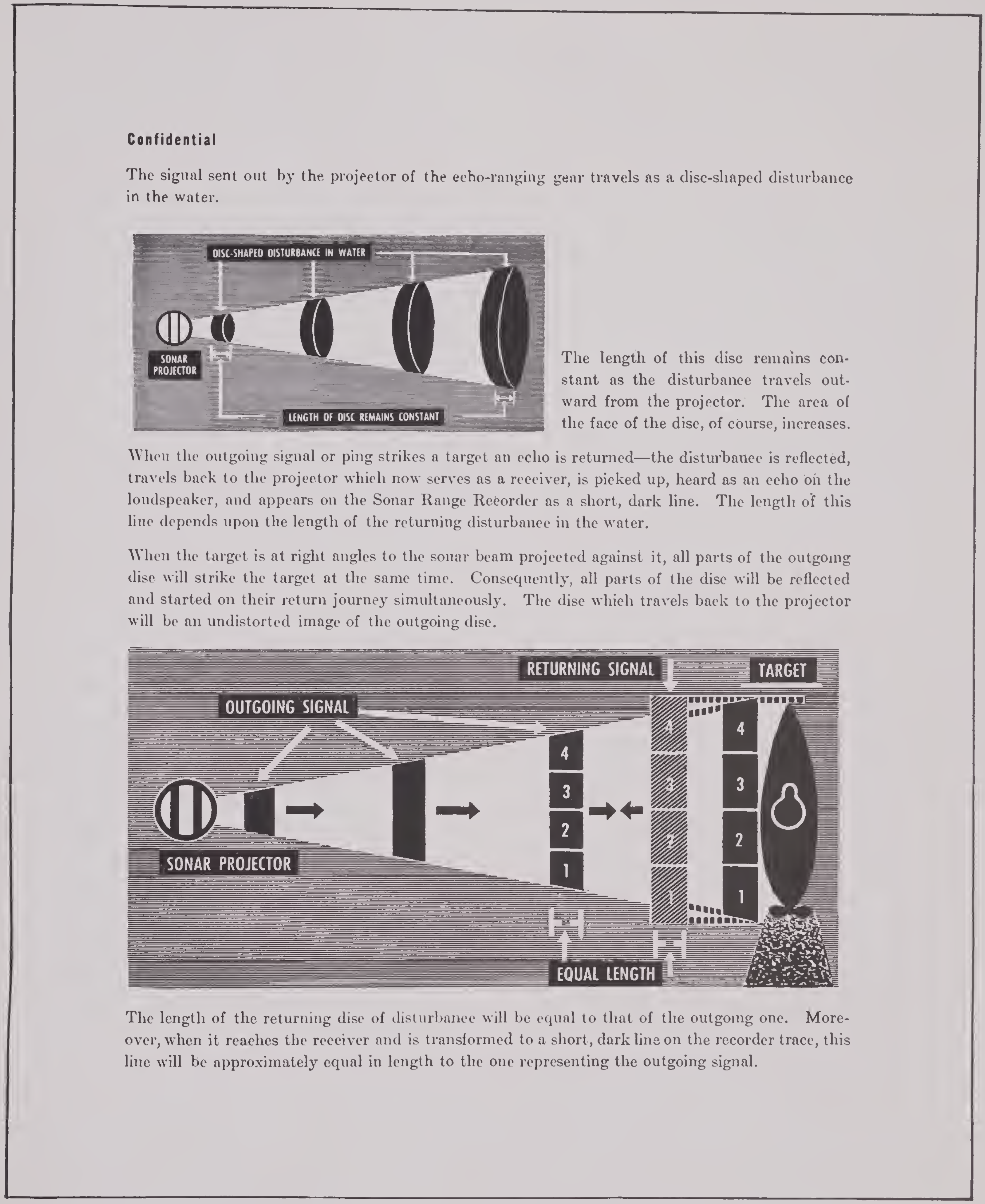
4. Set the GAIN control high enough so that you can recognize the echo readily, but not so high that the spot will be thrown off the BDI screen. In general, there should be an echo deflection of about ½ inch, although this will decrease as the projector bearing approaches that of the target. The exact size of the deflection also will vary from ping to ping. (See Section D 6.) *Note:* Varying the GAIN control of the BDI in no way affects the gain of the Sonar receiver.

5. If, at the instant you hear the echo on the Sonar loudspeaker, the trace on the BDI screen shows a sharp deflection to the right, train right. (A right deflection on the BDI screen means that the target is to the right of the projector bearing.) The distance of

OR
TRAIN RIGHT
CENTER BEARING
TRAIN LEFT

Fig. 13 Deflections and center indications of BDI.

FIGURE 4. Typical page from the BDI manual.



Confidential

The signal sent out by the projector of the echo-ranging gear travels as a disc-shaped disturbance in the water.

DISC-SHAPED DISTURBANCE IN WATER
SONAR PROJECTOR
LENGTH OF DISC REMAINS CONSTANT

The length of this disc remains constant as the disturbance travels outward from the projector. The area of the face of the disc, of course, increases.

When the outgoing signal or ping strikes a target an echo is returned—the disturbance is reflected, travels back to the projector which now serves as a receiver, is picked up, heard as an echo on the loudspeaker, and appears on the Sonar Range Recorder as a short, dark line. The length of this line depends upon the length of the returning disturbance in the water.

When the target is at right angles to the sonar beam projected against it, all parts of the outgoing disc will strike the target at the same time. Consequently, all parts of the disc will be reflected and started on their return journey simultaneously. The disc which travels back to the projector will be an undistorted image of the outgoing disc.

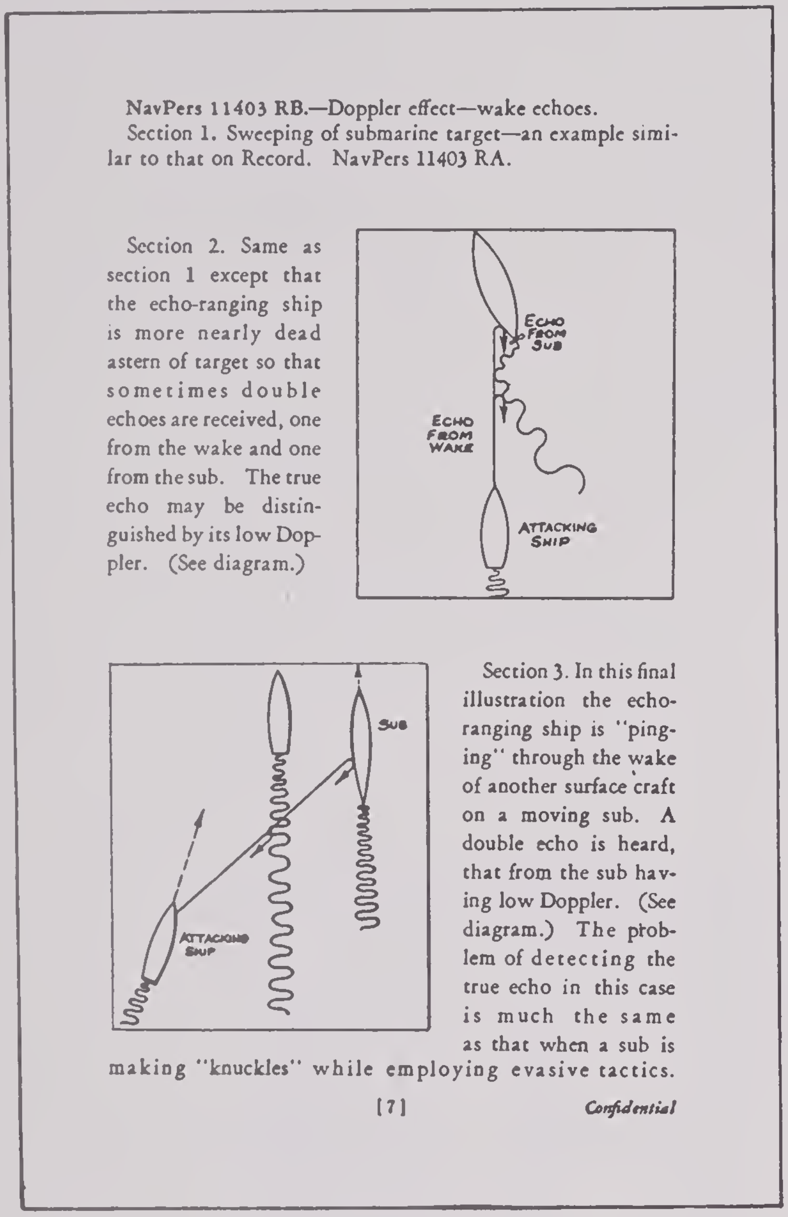
RETURNING SIGNAL
TARGET
OUTGOING SIGNAL
4
3
2
1
4
3
2
1
4
3
2
1
SONAR PROJECTOR
EQUAL LENGTH

The length of the returning disc of disturbance will be equal to that of the outgoing one. Moreover, when it reaches the receiver and is transformed to a short, dark line on the recorder trace, this line will be approximately equal in length to the one representing the outgoing signal.

FIGURE 5. Page from *Operation of the Sonar Range Recorder.*

were distributed by BuPers to all ASW ships and activities.

A set of recordings illustrating sounds heard over the anchored sono radio buoy was produced for BuShips distribution.



NavPers 11403 RB.—Doppler effect—wake echoes.

Section 1. Sweeping of submarine target—an example similar to that on Record. NavPers 11403 RA.

Section 2. Same as section 1 except that the echo-ranging ship is more nearly dead astern of target so that sometimes double echoes are received, one from the wake and one from the sub. The true echo may be distinguished by its low Doppler. (See diagram.)

Section 3. In this final illustration the echo-ranging ship is "pinging" through the wake of another surface craft on a moving sub. A double echo is heard, that from the sub having low Doppler. (See diagram.) The problem of detecting the true echo in this case is much the same as that when a sub is making "knuckles" while employing evasive tactics.

[7] *Confidential*

FIGURE 6. Page from manual for ASW training records.

Recordings were also used with several synthetic trainers. Five albums, 45 recordings, were prepared for use with the range recorder teacher, and over 100 recordings for the ERGT.

Assistance was given in preparation of two of the early movies for sonar operators. Other Navy films were edited and shortened so that they were better fitted to the instruction programs of the schools. Several sets of lantern slides were made for classroom use.

Devices for classroom demonstration were designed and constructed in small quantity. The "magnetic ocean," a sheet of metal on which several ships attached by magnets could be manipulated, was used in demonstrating relative motion and attack procedures. Other examples of this type of training aid were the animated lantern slides for teaching relative bearings and demonstrating search procedures.

3.2.5 Construction of Synthetic Trainers

At the beginning of 1942, the only sonar equipments available for operator practice were those aboard training ships and those which were part of the attack teachers. Sometimes as many as 50 students had to take turns at a single sonar stack. There was a serious need for synthetic trainers.

Bearing Teachers. Work was begun at once on a trainer which would resemble the sonar stack in appearance and operation, and would incorporate an automatic problem generator. The first unit of this device, called the *advanced bearing teacher* [QFD], was completed in May 1942 and four more were ready by the end of June. The advanced bearing teacher (see Figure 7) had all of the controls of the standard sonar stack, so that the student had much of the sense of working on real equipment. Range, bearing, bearing width, echo intensity, and doppler changed during the course of a problem

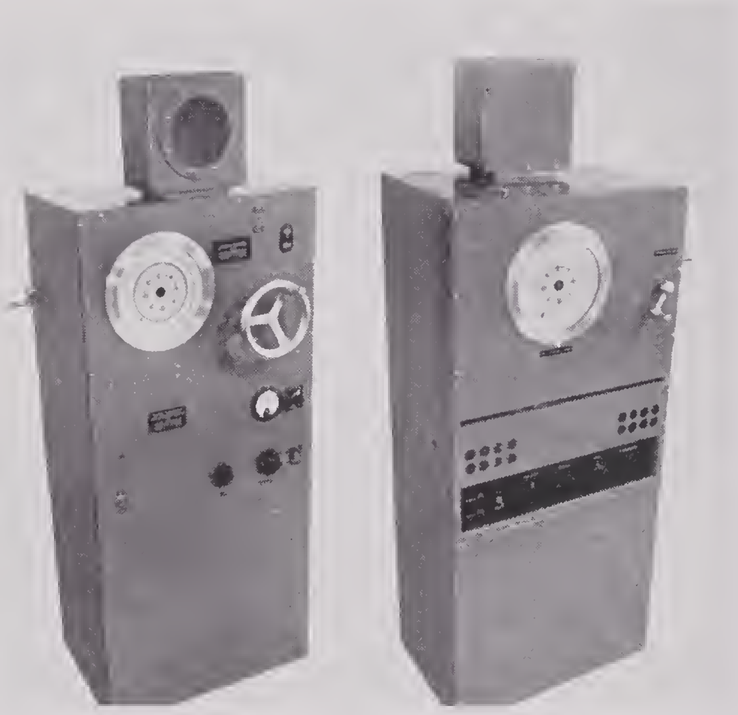


FIGURE 7. Advanced bearing teacher.

much as they would in an actual practice attack.

To fill the gap until the advanced bearing teacher could be produced in quantity, the *primary bearing teacher* [QFE], as shown in Figure 8, was hurriedly designed and ten units rushed through the UCDWR laboratory shops to become available in May and June. Although it did not bear too close a resemblance to the sonar stack, the primary bearing teacher could be used for drill on the more elementary procedures such as searching, reporting contact, crossing the target, and reporting doppler.

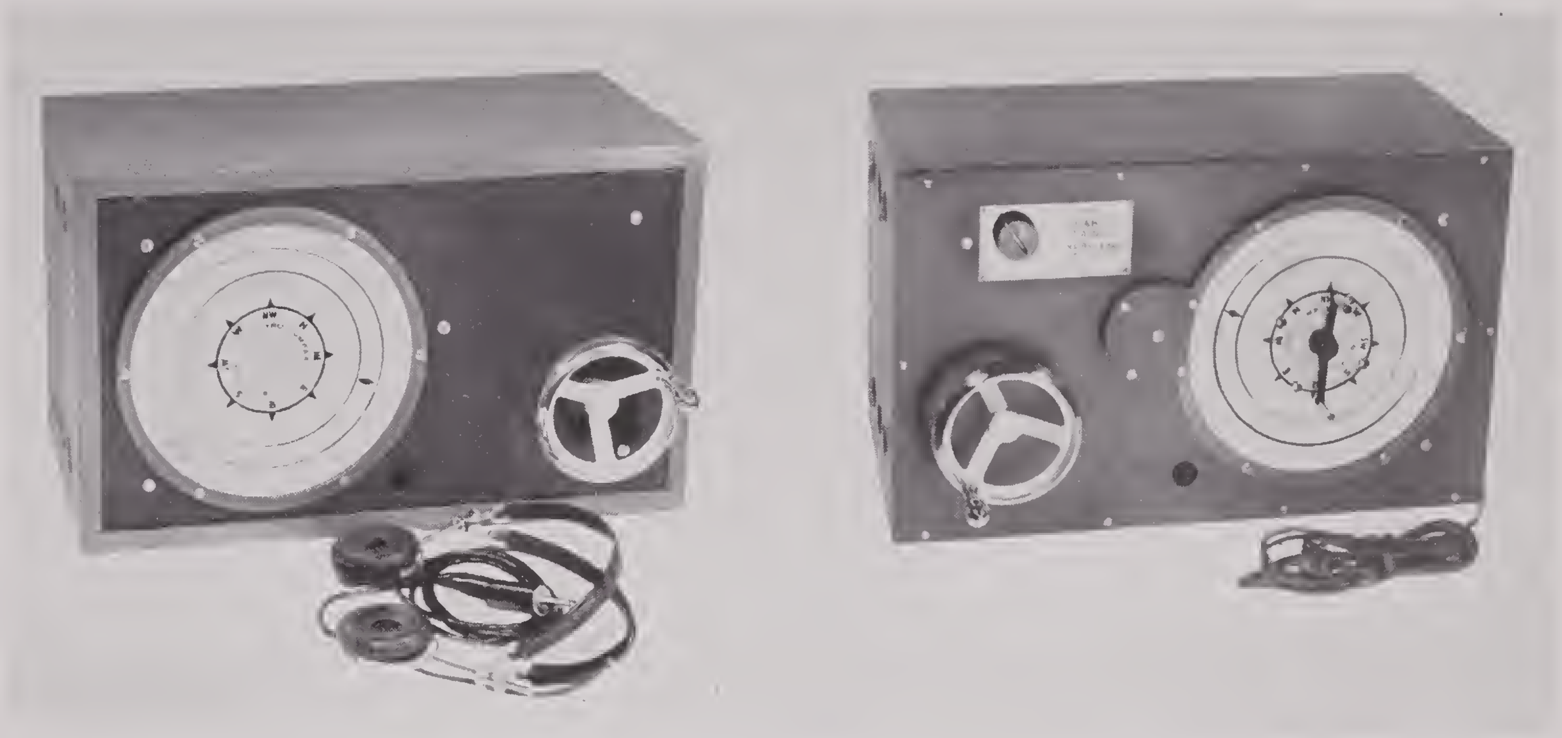


FIGURE 8. Primary bearing teacher.

By November 1942, 20 advanced bearing teachers and 50 primary bearing teachers had been supplied by outside contractors. Still larger quantities were later procured by the Navy. During early 1943 advanced bearing teachers became the backbone of the shore phase of operator training. Additional attack teachers had been installed, but the time for each student at the attack teacher sonar stack was still very limited. Primary bearing teachers were used only for rudimentary instruction in procedures. (A miniature version of the primary bearing teacher, called the *midget bearing demonstrator,* was later designed and a few built for shipboard use.)

Group Operator Trainers. The bearing teachers were essentially individual training devices. At each instrument one student acted as operator and another as problem-setter, while the instructor attempted to exercise general supervision over a number of such groups. To enable a single instructor to handle ten or more students effectively, it became evident that a better group training method was needed.

In the summer of 1943 a mass procedure teacher was being used by the British in training sonar operators at Key West. Although equipped only with manual controls, this group trainer enabled a single instructor to handle 10 to 20 students quite effectively. Group trainers adapted to U. S. Navy sonar equipment were devised temporarily at San Diego and Key West by enclosing each advanced bearing teacher in a sound-deadening booth and monitoring a series of them from a single central console. The success of this group instruction method in the winter of 1943-44 led to the development of a more refined group trainer for operator practice.

Two units of the *group operator trainer* (see Figure 9), one for each sound school, were built by UCDWR and installed at the sound schools late in 1944. A central master station controlled ten standard sonar stacks, each enclosed in a sound-deadening booth. An automatic problem generator provided a selection of six different attacks. Each student operated his stack independently. Repeaters on the central console indicated the movements of each projector, while a monitoring system enabled the instructor to listen in on any selected booth and give special instruction as needed. An important improvement over the advanced bearing teacher was the provision of a wake echo in addition to the submarine echo.

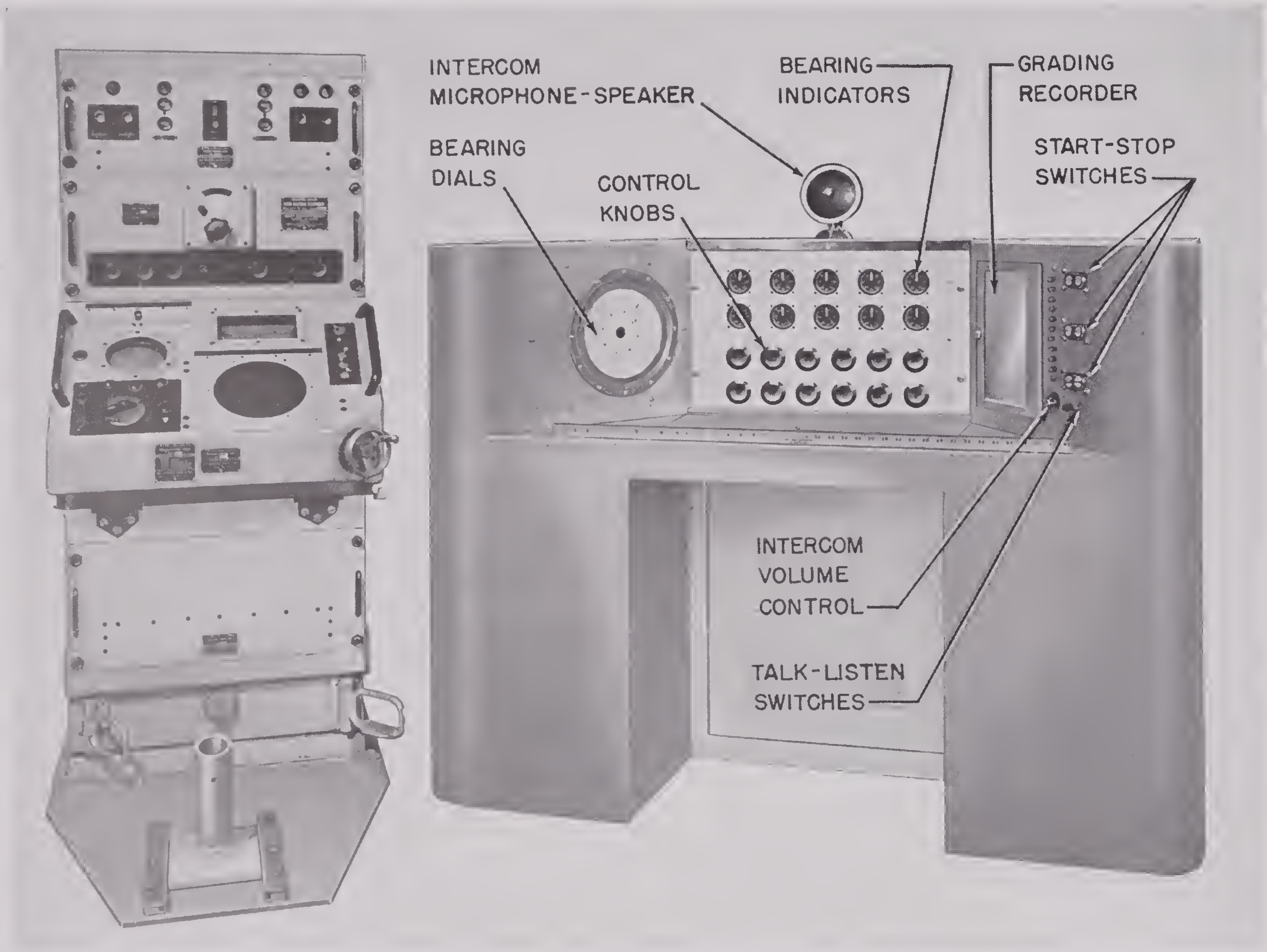


FIGURE 9. Group operator trainer.

Sound Range Recorder Trainers. By 1943 the sound range recorder had become an important part of ASW sonar equipment. Although range recorders had been installed on attack teachers, neither the traces nor the accompanying sounds were realistic. All practical drill in trace recognition had to be given during the sea phase of training.

In the spring of 1943 work was started at the CUDWR laboratory on the *sound range recorder teacher* [QFL]. Six laboratory-built units were completed by late summer and five of them delivered to ASW training centers. Two models of improved design served as production prototypes for the construction of 53 units which were built at the U. S. Navy Underwater Sound laboratory and distributed to the sound schools and other training activities.

This was a group trainer (see Figure 10) which used phonograph recordings of practice attacks to actuate a bank of five or more recorders and simultaneously produce authentic accompanying sounds. A 75-c tone, filtered out of the audio circuit, initiated stylus movement at the instant of each outgoing ping. Reverberations and echoes printed traces on the recorder paper exactly as on a shipboard installation. Each student was free to operate all the controls on his recorder independently, as he would in an attack. Five albums of recordings provided elementary instruction in operation of controls, demonstrations of various target aspects and changes of aspects, and a series of firing drills of graded difficulty. Each drill required the student to determine target aspect, set up the firing analyzer, judge the range rate, and fire at the proper time. An analysis of errors in reporting target aspect, setting range rate, and firing gave evidence of the student's progress. With the recordings which had been selected, the trainer provided practice on a wider range of attack situations than could be obtained during the sea phase of training.

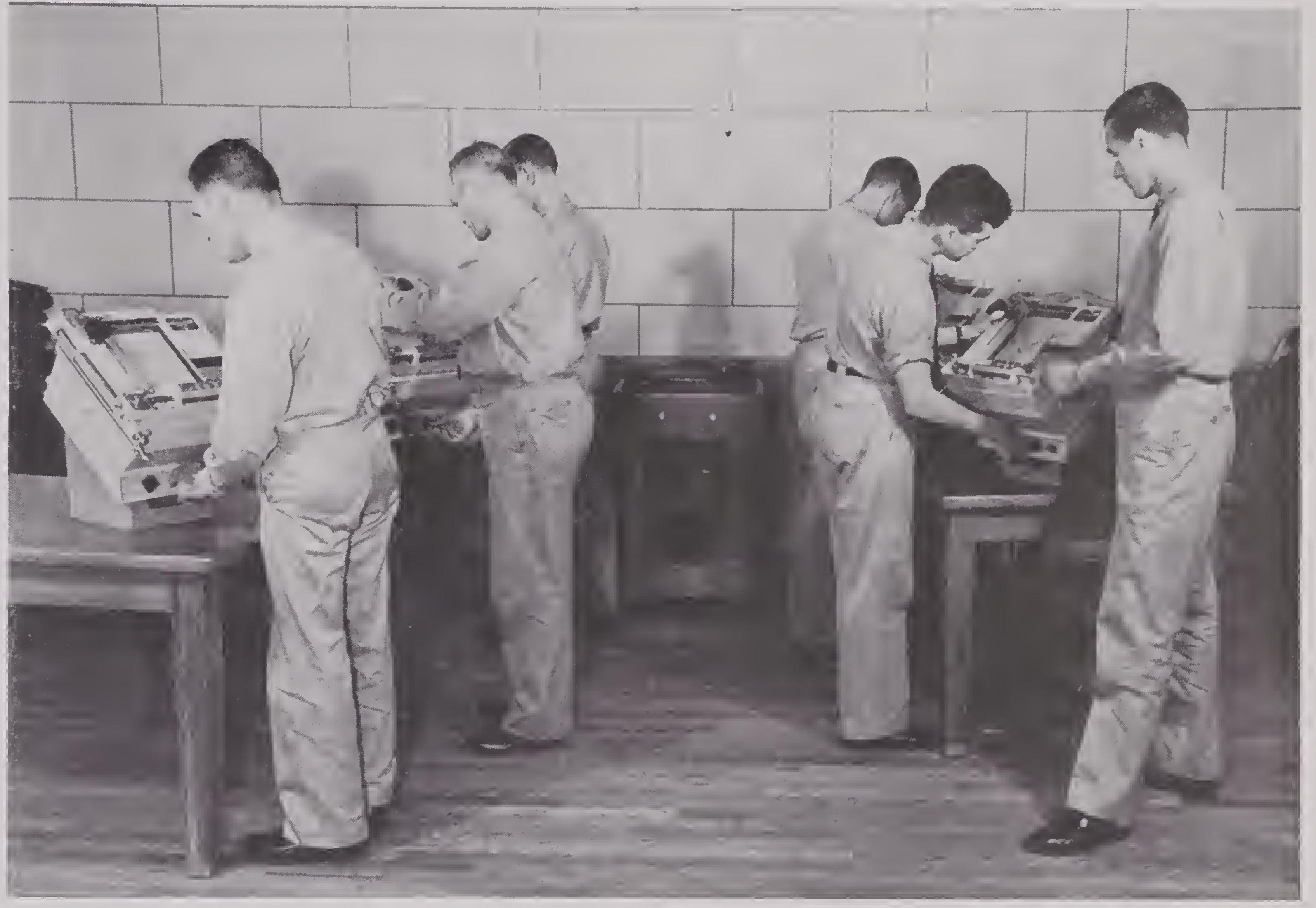


FIGURE 10. QFL range recorder teacher in operation.

A device called the *recorder trace projector* was designed as a classroom aid for teaching recorder operations to large groups. It consisted of a large-scale model of the sound range recorder face and firing time analyzer, with the window in the face replaced by a projection screen. Traces from an operating range recorder teacher or attack teacher recorder could be projected on the screen by means of an opaque projector. Several units were built but saw little actual service, because it was difficult to obtain clean-cut projected traces except under ideal conditions in a dark room.

A cardboard *model chemical recorder,* in which printed traces could be inserted, as designed by the training group at Key West and distributed by BuPers to training activities. A plastic *elementary range recorder teacher,* also using printed recorder traces, was designed by UCDWR and 25 units furnished to the sound school at San Diego. Both devices were largely replaced, even for elementary training, by the more effective range recorder teacher.

Echo Recognition Group Trainer. Throughout 1942 and 1943, a gradual evolution was taking place in the use of phonograph recordings for training sonar operators and sonar officers. Demonstration records, which had been produced for wide distribution to ships and training centers, were being replaced at the schools by *drill* recordings which required more active participation of the students, and by *test* recordings which gave measures of progress. ERGT was the culmination of this development.

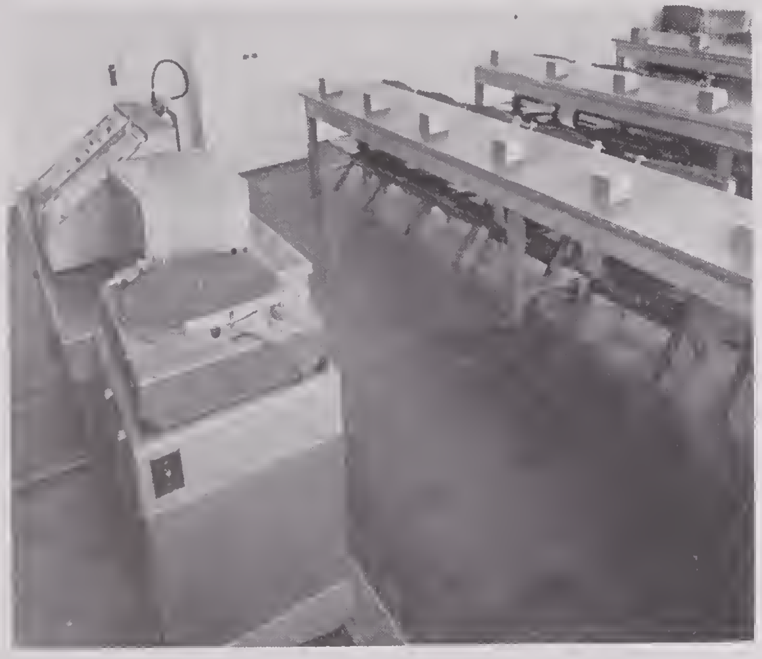


FIGURE 11. Echo recognition group trainer in use.

The first model was completed early in 1944 and improved designs were later installed at both sound schools (see Figure 11).

The echo recognition group trainer provided a central console from which an instructor could monitor drills and tests for a group of 10 to 20 students. Each student station was equipped with a silent switch for signaling answers. The signals were recorded graphically on a moving web of paper, giving an individual record for each student. Thus errors could be corrected and tardy responses noted immediately.

Each drill exercise was planned to give specific training in one or more types of sound discrimination, such as detecting faint contacts, distinguishing echoes through heavy reverberations, and distinguishing submarine echoes from wake echoes. Standardized tests measured student progress. Both drill and test materials were continually refined throughout 1944 and early 1945.

Attack Teacher Improvements. Minor improvements were made on the Sangamo attack teacher. A simple but useful change was the addition of a projected azimuth grid which permitted the instructor to maintain a constant check on the accuracy of reported target bearings. An experimental model of a *depth charge pattern recorder* was built as an adjunct to the depth charge driller on one of the attack teacher installations at Key West. Developed in a more refined form, this device was furnished to various training activities during 1944.

Practice Targets. In the spring of 1942, the sea phase of operator and officer training was seriously handicapped by a lack of sufficient target submarines for practice attacks. There was an immediate need for some sort of synthetic target to replace the missing submarines. The first repeater targets were laboratory-built and put into service that fall. Later on, many units of improved models were procured by the Navy and furnished to training activities.

The earliest models of practice targets were attached to a towed raft or to the keel of a small target vessel. Barrel-type stationary repeaters were also used for the most elementary instruction. To permit the attacking ship to maneuver freely, however, it was necessary to have a submersible repeater target which could be towed by a long line. Model SR-2, which operated at a depth of 60 to 90 ft at the end of a 1,200-ft towline, was produced in quantity during 1943 (see Figure 12). A few units of an improved model (SR-5) were used in 1944.

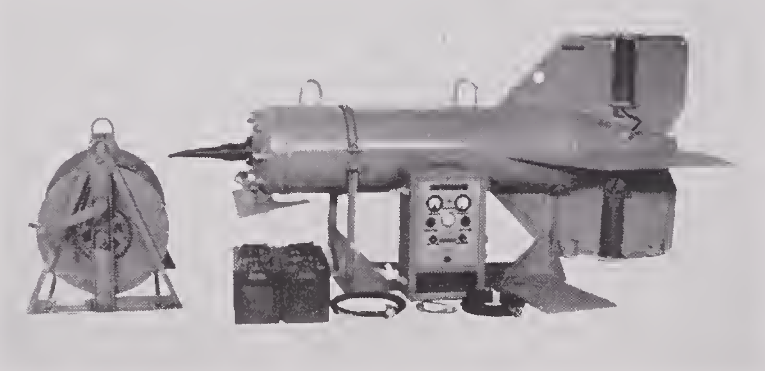


FIGURE 12. Echo repeater practice target, model SR-2, Navy designation OAS.

Essentially the same repeater mechanism, roughly simulating the return of echoes from a submarine, was used in all these practice targets. Doppler effect was produced if the repeater was moving. The best repeaters were not a perfect substitute for actual submarine targets since the traces received on the sound range recorder were oversimplified, principally because of the absence of wake effects. They proved extremely useful, however, in providing sea training for operators and officers during a period when sufficient submarines were not available.

Shipboard Attack Teachers. Another problem of growing importance was the need for some sort of shipboard training for the members of the sonar team *after* they left sound school. Opportunities for ASW vessels to make runs on our own submarines were rare, and there was no synthetic method of simulating an attack. Skills which had been well developed in sound school became inadequate from disuse.

Early in 1943, the UCDWR laboratory designed a simple electronic device which, when attached to the sonar stack aboard ship, could provide artificial echoes. Only a few of these *echo injectors* were built, since their usefulness was limited mainly to checking the alertness of the sonar operator on watch.

During 1943, development proceeded on the more complicated *shipboard antisubmarine attack teacher* [SASAT-A]. SASAT-A could be taken aboard a vessel and hooked directly into the sonar stack without interfering with normal operation (see Figure 13). The injected echo could be altered as to bearing, intensity, and doppler by manual control. The range of echo decreased automatically in accordance with the setting of a range-rate dial. Thirty units of SASAT-A, Model IV, were laboratory-built during the winter of 1943-44 and 100 units were later procured by the Navy. An experimental unit of Model V, incorporating BDI effects and equipped with true bearing dial coupled to the ship's gyro, was completed but never produced in quantity.

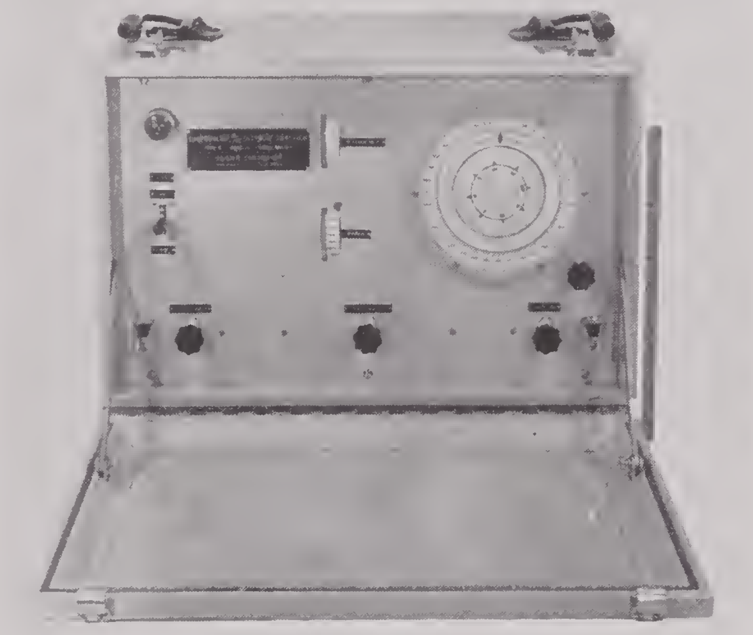


FIGURE 13. SASAT installed at a shipboard sonar stack.

SASAT-A proved most valuable for drilling the members of the sonar team in passing information and working smoothly together. It was also useful in providing refresher practice for sonar operators, although the echoes and recorder traces were oversimplified like those from a repeater target. A manual, giving the proper sequence of SASAT settings for simulating standardized attacks, was supplied as a guide in sonar team and operator training.

In some few instances, it was found possible to use SASAT-A for conning officer practice. For this purpose, however, no prepared sequence of settings could be employed. The SASAT controls had to be adjusted on the spot according to the maneuvers ordered by the conning officer. Few SASAT operators possessed the necessary skill in visualizing relative movement and simultaneously manipulating the dials to produce realistic effects. A SASAT *slide rule* for solving the relative movement problems was only a partial remedy. The obvious solution was a shipboard attack teacher employing an automatic problem generator. Such a device (SASAT-B) underwent experimental development, but never saw actual service.

Primary Conning Teacher. The *primary conning teacher,* as shown in Figure 14, was originally conceived as a device for the elementary training of ASW conning officers. Five experimental models were completed by the CUDWR laboratory in 1943 and 100 additional production models were procured by the Navy early in 1944.

In essence, the primary conning teacher was a miniature attack teacher without sound. The target was represented by a spot of light appearing on a maneuvering board screen. Target range and bearing were altered automatically to simulate the relative movement of ship and submarine. The problem-setter adjusted the speed and course of the submarine. The student conning officer directed the attacking ship by means of speed and rudder controls and pushed a button to indicate the dropping of depth charges or the firing of forward throwers. The accuracy of the attack could then be scored.

By the time production units were delivered, sufficient attack teachers had been installed at the sound schools and other ASW training centers to provide adequate training facilities for conning officers. A few units were used for shipboard conning instruction but the majority were employed as problem generators for exercises in plotting, for simulating two-ship attacks on the attack teacher, and for CIC training.

3.2.6 Instructors

In the summer of 1942 men with electronic training and teaching experience were recruited to serve as instructors in the sonar matériel schools at San Diego and Key West. They were employed by Division 6 until early in 1944, at which time they were replaced by Navy instructors or were given Navy commissions and retained.

In order to introduce new trainers or to initiate instruction on new equipment, members of the training group served as instructors for limited periods. Experimental instruction programs for the QFL and ERGT trainers were carried on for several months.

3.3 LIAISON

Liaison with ASW activities other than the sound schools was maintained through the Committee on Selection and Training, through special training representatives assigned to various training commands, and through contact with organizations such as the BuShips field engineers and the Antisubmarine Warfare Operational Research Group.

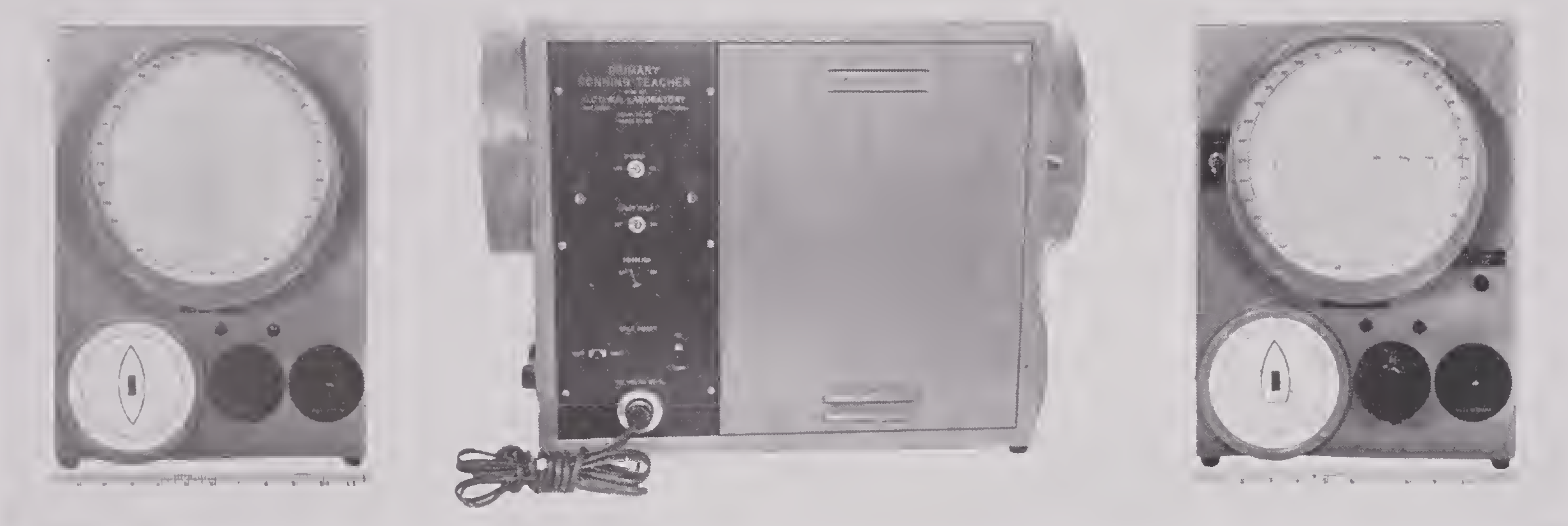


FIGURE 14. Primary bearing teacher.

The Committee on Selection and Training met at frequent intervals with representatives of various branches of the Navy—COMINCH, BuPers, BuShips, Coordinator Research and Development, BuMed, and others—to report on progress of work undertaken and to lay plans for new work. Individual members of the Committee also paid frequent visits to ASW training centers.

From June 1943 until March 1944, a training representative worked closely with COMINCH on several special training projects, most important of which were the training program for operators of the sound range recorder and the production of ASW training recordings.

A training representative assigned to COTCLant late in 1943 assisted the Antisubmarine Warfare Unit in a variety of ways. He compiled priority lists for the distribution of training equipment, organized an index of instructors, and acted as an advisor to the subordinate training activities. A representative assigned to ComDesPac served as both a training assistant and a field engineer. He helped not only in installing training equipment and starting training courses but also in the development, during training exercises, of new methods of attack.

Representatives of Division 3 and Division 6 were primarily responsible for instruction, given at San Diego, Key West, and Bermuda during 1943 and 1944, on the use of the "mousetrap." They directed loading and firing drills and analyzed and tabulated results of practice attacks.

Members of the training groups stationed at the sound schools and laboratories made increasingly frequent visits to ASW training centers during 1943 and 1944 in order to introduce new trainers or to assist in starting new courses.

The BuShips Field Engineers, although mainly concerned with engineering problems, took an active part in maintenance and operator instruction. They maintained close contact with the division laboratories and training groups. The Antisubmarine Warfare Operational Research Group [ASWORG] was an important source of information since it was often able to point to defects in training which showed up in operational results.

3.4 TRAINING PROGRAMS FOR LABORATORY DEVELOPMENTS

To get their products into use as quickly as possible, it was necessary for the research and development laboratories to assume certain responsibility for the organization of suitable training programs.

In retrospect, it is easy to see that a complete training program for a new piece of equipment should include the following: (1) operational research to discover the best procedures for its use, (2) development of training courses for operators and maintenance men, (3) preparation of operator and maintenance manuals, (4) design and construction of synthetic trainers, and (5) field service to initiate the training program. Under the stress of wartime conditions, such a systematic plan was not always followed.

Operational research was usually inadequate. During the period of experimental development, main attention was focused on getting the bugs out of the equipment, and any operational research was incidental. When the first production models appeared, they were sent directly to ships for installation. This policy was later changed so that early production models were earmarked for training schools, thus permitting some study of their proper utilization before many service installations had been made.

Plans for *training courses* had to be based on whatever experience the laboratory had been able to accumulate during field tests. Typically, the training course for operators as first planned was found to need considerable revision as Service experience with the equipment accrued. Maintenance instruction was usually satisfactory for the problems encountered during engineering development but had to be modified and expanded as information on field casualties became available.

Manuals were prepared in provisional form, because it was necessary to have instruction books to accompany the first equipments going into the field. These instructions were adequate for installation, routine operation, and normal maintenance but reflected the limitations of laboratory experience with service conditions. Whenever possible, the provisional manuals were later replaced by more complete instruction books.

Construction of *synthetic trainers,* if any were required, was usually under way before the final engineering development of the new equipment had been completed. However, a synthetic trainer often involved as difficult a set of design and construction problems as the original equipment. Consequently, only experimental models of trainers were ready by the time the first production units of new equipment went into service.

Field representatives did a great deal to make the training programs work under difficult conditions. Using whatever materials were available, they got courses started and trained Navy instructors to take over. They supervised the installation and demonstrated the use of synthetic trainers. When standard equipment was available, they assisted in making suitable training installations. Through their intimate contact with many different groups, they gathered a wealth of suggestions for improving training methods.

3.4.1 BDI Program

The *bearing deviation indicator* [BDI], developed by the Harvard Underwater Sound Laboratory [HUSL], was one of the few radical changes in U. S. sonar gear introduced during World War II. Instead of intermittent reports of cut-ons, BDI made possible continual and accurate center bearings of the target.

Since the maintenance problem was crucial, first attention was given to training the field engineers who were to supervise the installation of BDI equipment on ships. Beginning in 1943 as a series of informal lectures and demonstrations, the program was crystallized in February 1944 into a one-week course which was given at HUSL. The course covered the details of installation, adjustment, routine maintenance, trouble-shooting, operation, and the fundamentals of BDI trace interpretation. The BDI dynamic demonstrator, together with a signal injector (OTE-9), was designed and seven units were built for use in maintenance instruction. In collaboration with the instructional staff of ASWIS, BDI maintenance and operation instruction was introduced as part of the course for ASW specialists.

For operator instruction, HUSL designed and constructed four different types of synthetic trainers, OTE-2, OTE-4, OTE-5, and OTE-8. OTE-2, when connected to a standard shipboard sound stack, supplied artificial reverberations and echoes. Program cams were used to change range, bearing, and doppler in simulation of an attack. A graphic record was made of the correct bearings and the bearings obtained by the student. Only one unit was constructed; this was used for experimental work on the USS *Sylph*, one of the ships attached to AsDevLant. OTE-4 was an interim modification designed to furnish input signals to BDI equipment used with the Sangamo attack teacher. Only three units were constructed, because later modification of the attack teacher by the Sangamo Electric Company made the device unnecessary. OTE-5 modified the QFA-5 attack teacher to operate with QH-type sonar or to provide typical QH displays on the General Electric Company attack plotter. OTE-8 was an attachment for the QFD advanced bearing teacher (see Figure 15). It provided a BDI scope and the necessary equipment to produce BDI traces from the bearing teacher signals. Twenty-five units were procured by the Navy.

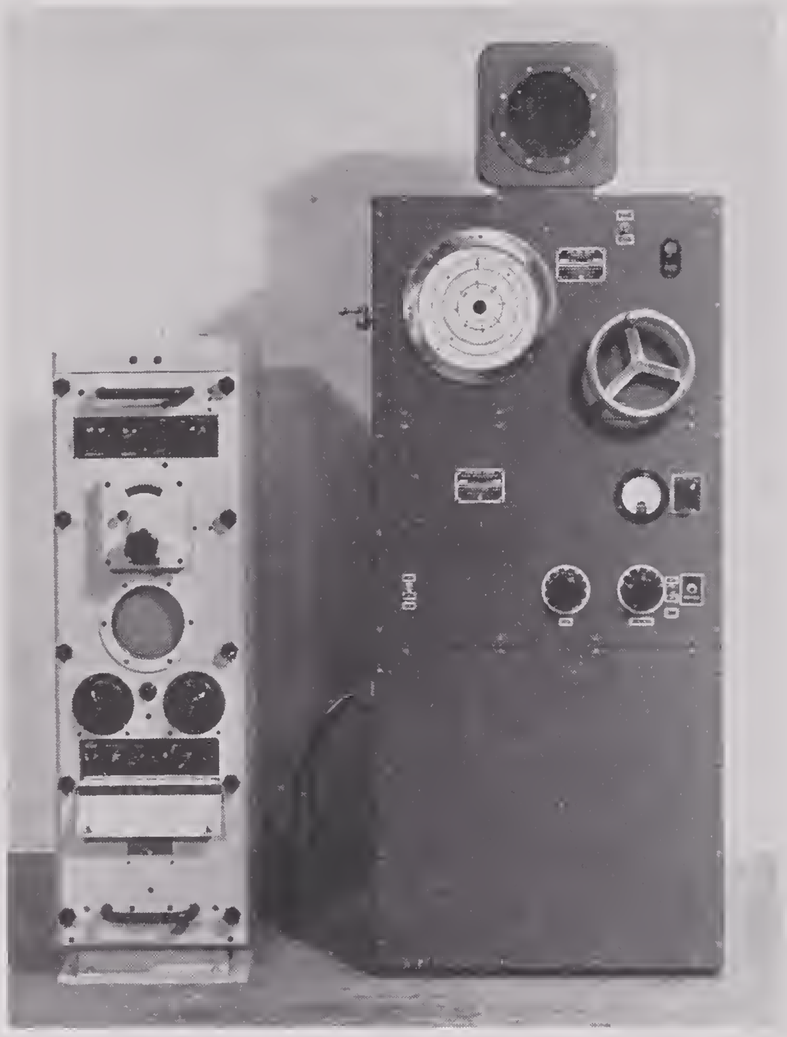


FIGURE 15. OTE-8, BDI attachment for the advanced bearing teacher.

During 1944 one model of a BDI adjunct for the advanced bearing teacher was constructed by the UCDWR laboratory. BDI simulation was also included in the group operator trainer. Since the group operator trainer was provided with a wake echo as well as a submarine echo, the BDI traces produced were more realistic than on any of the other training devices.

Instruction of officers in the use of BDI suffered from the delay in developing conning procedures based on the use of center bearings. At the time BDI became available, the official conning doctrine was based on the use of leading cut-ons and was totally unsuitable when BDI was used. Considerable confusion existed until an official method of BDI conning was finally adopted.

3.4.2 Bathythermograph Program

The first *bathythermographs* [BT] were supplied to ASW vessels early in 1942. At the request of BuShips, the Woods Hole Oceanographic Institution [WHOI] gave a month's course on the bathythermograph to three separate groups of BT officers. These officers were sent out to various commands, but many of them were assigned to other activities, only a few continuing in BT work.

Meanwhile informal instruction, first given occasionally to a few officers at WHOI, had been expanded by late 1943 into an intensive five-day course for ASW instructors and specialist students from ASWIS. During the following year some 600 officers attended this course. Field men from WHOI, although primarily engaged in gathering BT data for analysis, found many opportunities to give on-the-spot instruction at various ASW training activities. During 1942 and 1943, aid was given by WHOI in the preparation of BT manuals published by BuShips.

By 1944 research on the prediction of sound ranges from BT observations had produced much new information. In June 1944 UCDWR, in collaboration with BuShips, undertook a program of manual revision and of refresher instruction. Between June and October 1944 representatives visited training activities on the Atlantic and Pacific coasts, in the Mediterranean area, and in Africa and Brazil, giving instruction on the latest range-prediction methods. They worked closely with ASW instructors who were directing refresher training. Preparation of BT manuals continued through 1944 and 1945.

3.4.3 ERSB and DRSB Program

The previous sections of this chapter have dealt with the training of officers and men of surface craft. The expendable radio sono buoy [ERSB] and the directional radio sono buoy [DRSB] were sonar detecting devices dropped from aircraft. The officers and men trained to use and maintain these devices were, for the most part, from the air forces.

In the late summer of 1942, instruction books and training recordings for the ERSB were prepared by the CUDWR laboratory and distributed to Army and Navy groups which were testing the first experimental models of the buoy. During February and March 1943, several groups of Army Air Force and Navy officers and men were sent to the Naval Training School, Fisher's Island, and given a special course on the use and maintenance of buoy equipment. The program was planned and to a large extent conducted by members of the CUDWR staff. The officers and men trained at Fisher's Island returned to their stations to instruct the crews of planes receiving the first production units.

Engineers who had worked with the ERSB development group in the CUDWR laboratory visited the Army and Navy bases where ERSB equipment was being used, supervised the installation of receivers in planes, directed the testing and readying of buoys, and assisted in the training of operators, maintenance men, and flight crews. This field service was a major factor in the effective use of the ERSB. During 1943, 1944, and early 1945, three to eight laboratory representatives were engaged in field work throughout all areas in which extensive training was being carried on: the Caribbean, North Atlantic islands, England, the Mediterranean, and the Pacific. Their work was supplemented in 1944 by the Aircraft Coordinating Group organized under the Naval Research Laboratory. Members of the Aircraft Coordinating Group were given special instruction in the use and maintenance of buoy equipment at New London and at the ComAirLant Sono Buoy School in Norfolk.

In the spring of 1943, as the production of ERSB equipment increased, additional training materials were required. Three 15-minute slide films with sound, describing the ERSB and how to use it, were produced by CUDWR and distributed by BuAer. The ERSB trainer, which operated from phonograph recordings, was designed and two units built, one for AsDevLant at Quonset and the other for ComAirLant at Norfolk. Instruction books were revised to cover modifications in the equipment and new features of its use.

A sono buoy school was established by ComAirLant at Norfolk in May 1944. The CUDWR staff trained instructors for this school, helped them in planning lectures and laboratory sessions, and conducted part of the courses during the early days of the school. On several later occasions, instructors from the school were given special courses at the laboratory.

During the summer of 1944, a new set of ERSB phonograph recordings, giving more extensive examples of ship sounds, was completed and turned over to BuAer for distribution. A training program for DRSB, which was then getting into production, was also initiated. Operation and maintenance instruction books were written, a set of phonograph recordings prepared, a descriptive movie produced, and a synthetic trainer constructed (see Figure 16). All of these were completed and ready for use by the time the first production units of DRSB were delivered. Instructors from the ComAirLant Sono Buoy School were given special training on DRSB. Courses in operation and maintenance were outlined and introduced at the ComAirLant school.

During the spring of 1945, the activities of CUDWR in connection with ERSB and DRSB training gradually decreased as the programs of the ComAirLant school and the Aircraft Coordinating Group became fully effective.

3.4.4 MAD Program

The *magnetic airborne detector* [MAD] was developed by the Airborne Instruments Laboratory [AIL], Mineola, L. I. All assistance to the Navy in training men to use and maintain MAD was handled by the laboratory personnel.

Between September 1943 and June 1944, 346 officers and men attended courses at Mineola for pilots, operators, and technicians. The pilot and operator courses were each two weeks in length, with pilots and operators paired in

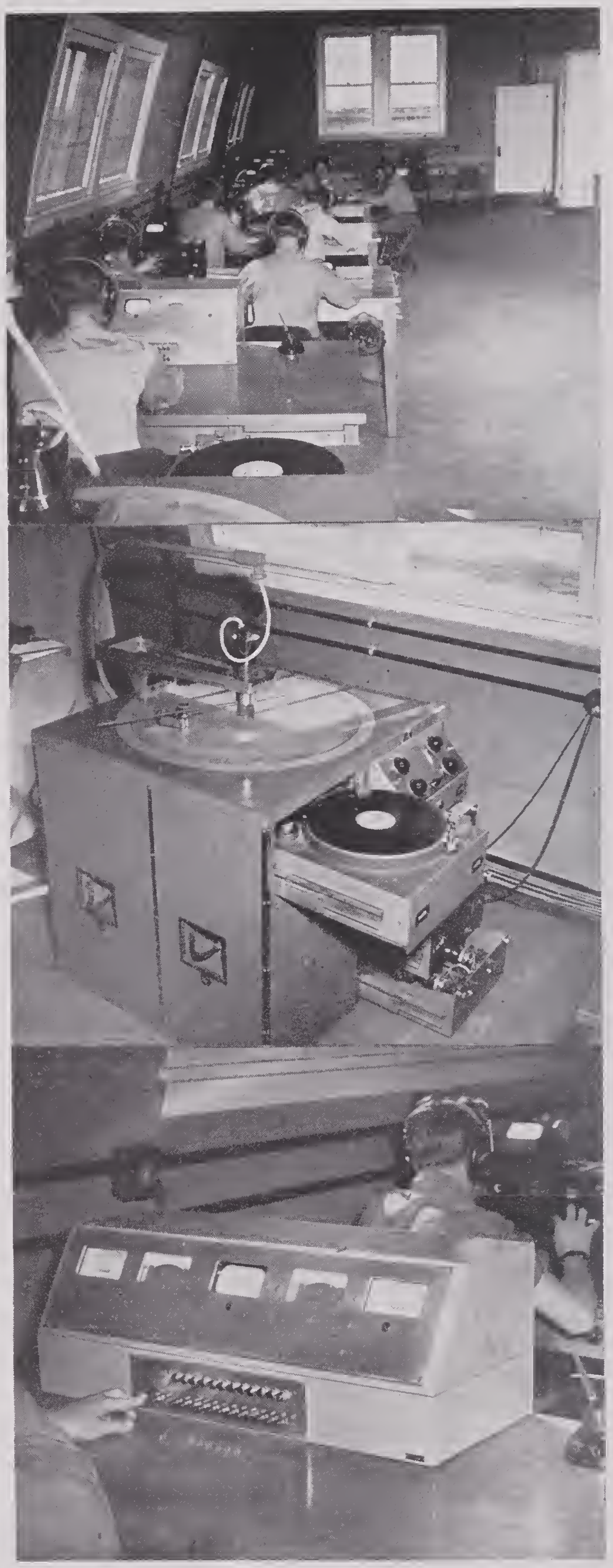


FIGURE 16. DRSB trainer in operation.

teams during the last two days. The technician's course lasted four or five weeks and concentrated primarily on practical maintenance and trouble shooting. For the elementary training of operators, a setup of eight standard MAD equipments was used, with a signal generator to furnish magnetic indications simultaneously to all stations.

Two synthetic trainers were developed by AIL.[a] The *pantograph tactics trainer* was designed to teach the elements of MAD tactics to pilots. The student pilot on one side of a screen traced a search pattern, while an instructor on the other side reported each time the pilot made contact with a simulated submarine track.

The *magnetic attack trainer* was an elaborate device in which a model submarine and a model airplane were maneuvered by remote controls. The model submarine generated a magnetic field scaled to that of an actual submarine. The model plane was equipped with a detector which produced MAD indications at the pilot's station whenever the plane came within proper range of the submarine. Duplicate MAD indications were produced at the operator's station, so that the pilot and operator could be trained as a team. A later model of the device, including both MAD and ERSB signals, was constructed to simulate blimp operation. Pilots and operators were given some training in the use of the ERSB as well as MAD.

3.5 ASW TRAINING AIDS

Phonograph recordings, slides and films, and classroom teaching devices prepared by Division 6 are listed in Appendix III. Instruction books are listed in the bibliography.

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[a] See STR Division 6, Volume 5, Chapter 7.

Chapter 4

SELECTION OF SUBMARINE PERSONNEL

DIVISION 6 DID NOT participate extensively in research on the selection of submarine personnel, but it did on several occasions supply technical assistance for limited periods. For six months during 1942, a psychologist and a clerical assistant worked with the Medical Research Department, Submarine Base, New London, on a research program for sonar operator selection. Further incidental assistance was given to the same department at a later date. From June through December 1944, three members of the training group worked with ComSubTrainPac in developing a system of personnel classification and establishing entrance requirements for submarine training courses at Pearl Harbor.

4.1 SELECTION FOR SONAR OPERATOR COURSES

The problem of selecting men to be given submarine sonar operator training was quite different from the parallel problem which had been encountered in the Antisubmarine Warfare [ASW] work. There was no rating of submarine sonarman prior to February 1945. Seamen and men rated in certain other specialties were assigned to stand sonar watches.

TABLE 1. Complement for submarines of the *Salmon* (SS182) class.

Rate	Standard complement	Eligible to stand sonar watch	Eligible but seldom assigned	Not eligible
GM	1	1	..	..
TM	7	..	7	..
TME	2	..	2	..
QM	3	..	3	..
SM	1	..	1	..
FCS	1	1	..	..
S	11	11	..	..
RM	4	4	..	..
RT	2	2	..	..
MoMM	16	..	..	16
EM	10	..	..	10
F	4	..	..	4
Y	1	1	..	..
PRM	1	1	..	..
SC	2	..	2	..
Bkr	1	..	1	..
StM	2	..	2	..
Total	69	21	18	30

It was considered desirable to have approximately 14 men per boat trained in sonar operation. Table 1 shows that the ship's complement included only 21 men in the rates usually assigned to sonar duty. This meant that at least two-thirds of the men in these ratings had to be given sonar operator training. Contrast this situation with that for surface craft where the best operator material could be chosen from large training camp populations. For submarines, the primary problem was to eliminate men who were dangerously deficient or inept, rather than to select the best qualified. The addition in February 1945 of one rated sonarman to each boat's complement made little difference, since the majority of sonar watch-standers still had to come from other rates.

The Medical Research Department, Submarine Base, New London, had begun the study of sonar operator selection methods in 1941. Early in 1942 a psychologist was assigned by Division 6 to work with the Medical Research Department in planning a testing program and analyzing the results, coordinating this investigation with the research at Key West and San Diego on selection of surface craft sonar operators.

During the spring of 1942, selection tests were administered experimentally to students entering the sonar operator course at the Submarine School. The battery included the Otis Test of Mental Ability, all the tests of the new edition of Seashore Measures of Musical Talent, and an Individual Pitch Discrimination Test which had been developed locally. Final grades in the operator course were used as criteria in validating combinations of the test results. For eliminating the men most likely to fail, a scheme using the Otis, Seashore Pitch and Rhythm, and the Individual Pitch Discrimination tests as three successive hurdles was found to be effective.

Results[11] with an experimental group of 121 students in the submarine sonar operator course are shown in Table 2. This battery of tests and standard audiometer measurements were used thereafter as a basis for telling the Submarine School which men were least qualified and which were best qualified for sonar operator training.

Table 2. Validation of the submarine sonar operator selection plan.*

	Submarine School, New London (Criterion, final grades)		
	Unsatisfactory	Satisfactory	Number
Passed all 3 hurdles	20%	80%	70
Failed one or more	53%	47%	51

* Passing scores on tests were Otis, 36; average of Seashore Pitch and Rhythm, 45; and Individual Pitch Discrimination, 35. All scores are standard scores based on a mean of 50 and standard deviation of 10. The table may be read as follows: Of the 70 men who successfully passed all three hurdles, 80% made satisfactory grades in the sonar operator course; 20% unsatisfactory, and so on.

4.1.1 Audiometer Studies

Several investigations were conducted in connection with the use of audiograms in sonar operator selection. The classification scheme shown in Table 3 was adopted in order that audiograms might be grouped for statistical study.[a]

Based on the classification of Table 3, an abbreviated procedure for determining audiograms was developed.[12] Each of 1,050 audiograms was classified twice, first using the threshold measurements made at seven frequencies (128, 256, 1,024, 2,048, 4,096, 8,192) and then using the measurements for only four frequencies (256, 1,024, 4,096, 8,192). It was found that every ear classified as deficient by the seven-frequency audiogram was also classified as deficient by the four-frequency audiogram. In only 7 of the 149 deficient cases was there a change in the nature of the deficiency classification. On the basis of this evidence, the four-frequency audiogram was used for the routine testing of sonar operator candidates.

A study was made of the value of audiograms in predicting listening ability.[13] Student operators were classified as having "normal" or "deficient" hearing. The normal group included the following audiogram classifications for the two ears: both N, N and ND1, ND1 and ND2, N and H2, ND1 and H2, H1 and H2. All others were classed as deficient. Out of a total of 1,700 subjects, 1,344 (79.1 per cent) were classified as normal and 356 (20.9 per cent) as deficient. The two groups were compared on the basis of various criteria, such as final grade in the operator course and scores on test target contacts during operation of listening equipment. For all criteria, the group classified as normal was slightly superior. The most significant results

Table 3. Classification of audiograms.

Classification	Definition
N	Includes all audiograms whose general course is not lower than 15 db below normal. For one or two tones a loss of 25 db is allowed if all others are 15 db or less.
D1	General hearing loss from 20 to 35 db at all frequencies. Curve of audiogram straight with no marked dips or slope.
D2	General hearing loss from 40 to 55 db at all frequencies. Curve of audiogram approximately straight.
D3	General hearing loss 60 db or more at all frequencies. Curve of audiogram approximately straight.
ND1	Local hearing loss of 30 to 35 db in a range of one octave or less.
ND2	Local hearing loss of 40 db or more in a range or one octave or less.
H1	High-frequency hearing loss 40 db or more at 16,384 c. Other frequencies normal. Since audiograms are commonly run only for frequencies through 8,192, the H1 class is usually considered normal (N).
H2	High-frequency hearing loss, 40 db or more at 8,192 and above. Hearing for lower frequencies normal.
H3	High-frequency hearing loss, 40 db or more at 4,096 and above. Hearing for lower frequencies normal.
H4	High-frequency hearing loss, 40 db or more at 2,048 and above. Hearing for lower frequencies normal.
D1-H2, etc.	Combinations of above for audiograms which cut across classes.

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[a] This method of classifying audiograms was devised by E. G. Wever, Princeton University. It is a modification of a scheme originated by S. R. Guild, Johns Hopkins University.

were obtained with the criterion of contact detection scores made on sonic listening equipment. These results are shown in Table 4.

TABLE 4. Influence of hearing loss on listening performance.

New London (Criterion, scores on contact detection tests using sonic listening equipment)

	Unsatisfactory*	Satisfactory	Number
Men with "normal" hearing	18%	82%	107
Men with "deficient" hearing	35%	65%	23

* Lowest 20 per cent of the group in contact detection scores.

4.1.2

Later Assistance

Active aid to the Medical Research Department was discontinued in October 1942 because of the greater urgency of other aspects of the selection and training programs. In 1944 and 1945, when the division had become involved in the training of submarine sonar operators, interest in the problem of selection was renewed; it was considered secondary, however, to that of training.

Preliminary experiments by the training group indicated that a testing procedure using the propeller noise discrimination meter[14] (see Figure 1) could be made sufficiently reliable for group testing purposes.[15] Target Discrimination Test recordings were also prepared in order to measure the student's ability to pick out a particular ship's propeller sounds from several similar propeller sounds, all recorded over standard submarine sonar listening equipment. The test had good face-validity, since it was essentially a job sample; satisfactory reliability was indicated in preliminary experiments.[16] Both the propeller noise discrimination meter and the target discrimination test recordings were turned over to the Medical Research Department for further experimentation.

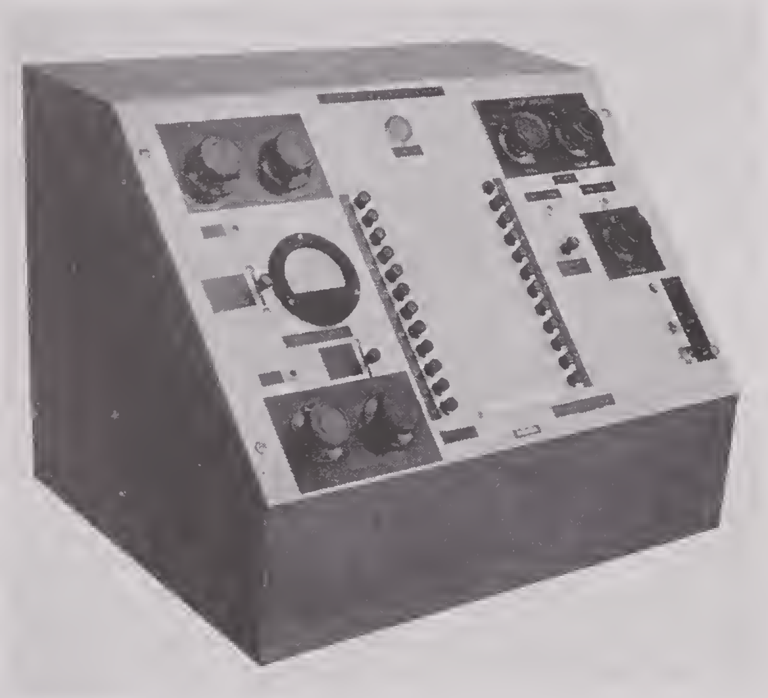

FIGURE 1. Propeller noise discrimination meter.

4.1.3

Discussion

It has already been pointed out that no systematic program of submarine sonar operator selection research was attempted by Division 6. If all men who stand sonar watches were rated as sonarmen or if some joint rating such as Communications Mate were established to cover operators of sonar, radar, and radio equipment, such a program might be worth while. It might then be possible to select the best-qualified men from a relatively large group, preferably before their assignment to submarine service.

A number of suggestions can be made about any further research on the selection of submarine sonar operators.

1. Before any marked advance can be made in selection methods, better criteria, i.e., better measures of operating skill under realistic conditions, must be obtained. Grades on written examinations are of little value. Measures of performance on well-designed synthetic trainers or on standard equipment during underway training may be used if reliable scoring methods can be developed. Measures of performance under conditions of excitement and stress are also necessary although difficult to obtain.
2. Tests which predict ability to perform under stress should be developed. Such tests cannot, however, be validated until the criteria mentioned above are available.
3. Comparisons should be made of the merits of tests which measure relatively discrete aptitudes (e.g., pitch discrimination) and tests of the job-sample type (e.g., the target discrimination test previously described).
4. New tests to measure the total pattern of

sensory-motor skills required in operating sonar equipment should be devised and tried.

5. The selection program should be re-examined at frequent intervals. Each change in design of sonar equipment means a change in the operator requirements, and the battery of selection tests must be revised to keep pace.

4.2 CLASSIFICATION PROGRAM FOR COMSUBPAC

In July 1944, a Division 6 group working with ComSubPac was asked to assist in establishing systematic methods for selecting men to attend the various training courses conducted by ComSubTrainPac at Pearl Harbor. In response to this request, the following program was proposed[17]:

1. That a classification system be established to determine the capabilities of every enlisted man assigned to ComSubPac at Pearl Harbor.
2. That the classification be based upon the tests in the Navy basic battery plus additional information as to education, experience, and interests obtained by means of a written questionnaire.
3. That the test scores and other pertinent information for each man be recorded on a qualification card, one copy of which would be placed in the man's service record folder and the second filed by ComSubTrainPac.
4. That entrance standards be established for every course on the basis of preliminary research studies and that all men assigned to any course be required to meet its standards.
5. That a program of research be continued in order to improve the validity of the entrance standards and to change them as job requirements changed.

The program was adopted and the work started in August 1944. To carry out the initial classification all men were given the following tests:

1. Basic Battery (four tests: General Classification, Reading and Arithmetical Reasoning, Mechanical Aptitude, Mechanical Knowledge—NavPers 16502, 16512, 16524, and 16533 respectively).
2. Clerical Aptitude Test (NavPers 16540).
3. Enlisted Personal Inventory (NavPers 16842).

They also filled out a personal history questionnaire devised by the Division 6 group. By November, 1,300 men had been processed.[9] Test scores and other information were recorded on a special qualification card. This card was used because the service records of the majority of the men did not contain the standard Navy qualification chart properly filled out, and no supply of blank forms of the standard chart was immediately available.

After this preliminary testing of the entire group on station, only the incoming drafts of new men had to be examined. In most cases, these men had standard qualification charts in good order, so that it was not necessary to administer the entire battery of tests. On November 20, the task of testing and recording was assumed by the Classification and Training Officer, Staff, ComSubTrainPac, a position created especially to take over the work of the Division 6 group.

In the meantime, in order to eliminate waste in the use of training facilities as quickly as possible, tentative entrance standards for courses were established somewhat arbitrarily. Experience, interest, and past training were considered as well as the results of aptitude tests which were known to have predictive value in similar situations. Preliminary studies were made correlating test results and questionnaire information against grades obtained in the various training courses. Because of the small number of students in some courses and the inadequacy of course grades as criteria, the validity of the entrance requirements could be established in only a limited fashion.

When the members of the division group terminated their work at Pearl Harbor in December 1944, responsibility for the classification program was taken over by the Classification and Training Officer.

4.2.1 Comment

The move to establish a systematic program for assigning men to training courses on the basis of their aptitude and experience was a long-delayed step forward. Badly needed training facilities were being wasted on men who had neither the aptitude nor the background knowledge to benefit from them. The preliminary entrance standards, although they were tentative, served to reduce this wastefulness by eliminating the men who were least qualified.

To accomplish the broader objective of selecting the best-qualified men for each training course would require a long-range program, starting with a set of thorough job analyses and ending with a continuing process of revalidation. In this sense, what was accomplished at Pearl Harbor was only a beginning.

Chapter 5

TRAINING OF SUBMARINE PERSONNEL

Division 6 began to take an active part in the training of submarine personnel in the late summer of 1943. By then sonar equipment developed by the division laboratories was in production and was being installed on submarines. As with antisubmarine warfare [ASW] developments, it was necessary to develop training programs to introduce the new equipment.

The work of organizing programs for laboratory developments led to requests for assistance in other phases of submarine training. At this point, experience gained in the earlier ASW work proved a marked asset. Effort was concentrated on planning and developing entire training programs rather than on fulfilling scattered requests for specific kinds of assistance such as construction of trainers or preparation of training aids. As a result it was possible, particularly in connection with sonar, radar, and voice communications training, to carry out systematic programs which included the following major steps.

1. Analysis of training needs to determine the number of men to be trained and the knowledge and skills which they were to be given.
2. Survey of existing training facilities and planning of additional facilities so that training needs could be met.
3. Planning of course curricula designed to satisfy the training needs and to make the most effective use of existing facilities.
4. Training of Navy instructors for the particular program in which they were to be engaged.
5. Preparation of achievement tests, both objective-type written examinations and measures of performance.
6. Preparation of training aids, such as manuals for instructors and students, demonstration equipment, demonstration and drill recordings, films, lantern slides, and charts.
7. Design and construction of synthetic trainers.
8. Field work by training group representatives.

A brief account is given below of the assistance provided by Division 6 to submarine schools and training commands.

5.1 SONAR TRAINING PROGRAMS

Division 6 participation in submarine sonar training began when the first units of the new JP sonic listening equipment were installed on submarines during the summer of 1943. To the Columbia University Division of War Research [CUDWR] laboratory, which had designed and developed JP, fell the task of providing training for men who were to operate and maintain the equipment. Beginning with this training program for JP, Division 6 took an increasingly active part in the rapid expansion of submarine sonar training.

5.1.1 JP Training Program

Initially, JP training was given to the crews of individual boats during underway exercises. As the production rate of JP gear increased, it became necessary to train men more rapidly; therefore instruction was given ashore as well as underway.

To implement the training courses, an assortment of training aids was prepared. Suggested course outlines and lesson plans were compiled in handbook form for instructors. A manual on maintenance and trouble-shooting and an operator's manual, *Topside Listening*, were written and printed for student use. An album of phonograph recordings was produced. Phonograph playbacks were procured and modified so that recordings could be played through the JP amplifier, thus enabling the instructor to demonstrate use of gain and filter controls.

A *JP amplifier-demonstrator* was provided for maintenance instruction. It consisted of a large wooden mockup of the JP amplifier. A blown-up wiring diagram and the actual amplifier parts wired to permit voltage and resistance checks were mounted on the demonstrator chassis.

JP training kits containing the above equipment as shown in Figure 1, plus standard JP amplifiers and miscellaneous small parts of the JP gear, were assembled and shipped to submarine training activities at the following places: New London, Portsmouth, Key West, Manitowoc, Hunter's Point, San Diego, Pearl Harbor, and Midway.

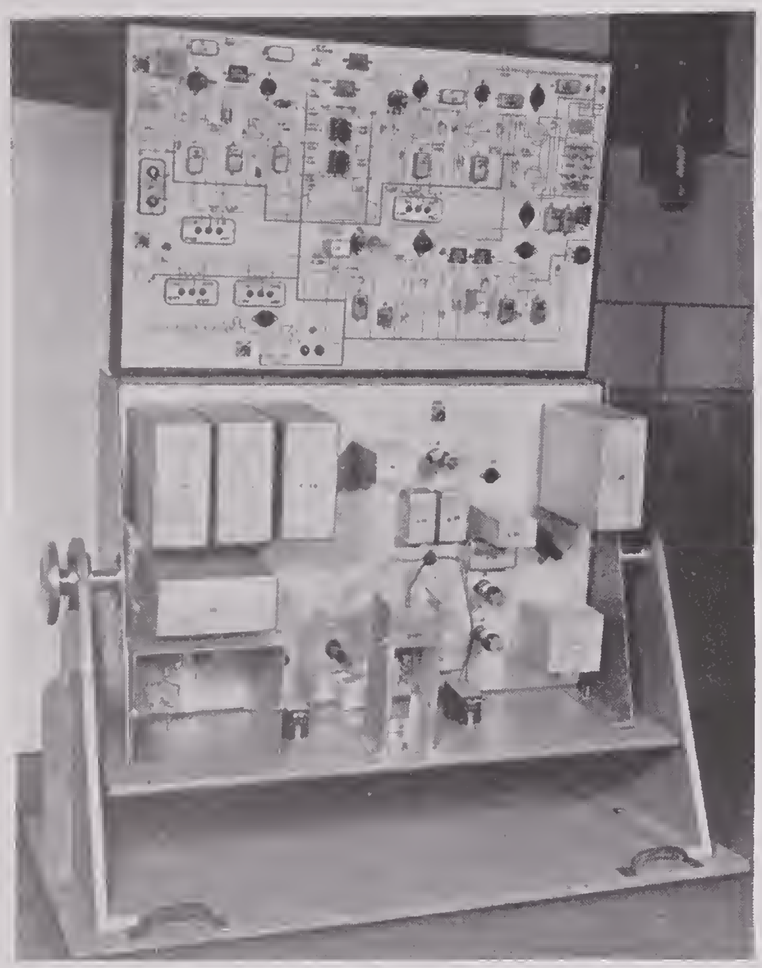

FIGURE 1. Main components of JP training kits.

Representatives of the Division 6 training group visited each of these bases, started a training course, and gave instruction until a Navy instructor could be trained. Since Navy instructors were not always available the training group representatives sometimes continued to conduct classes for several months. The scope of the JP program is indicated by the fact that, between November 1943 and March 1945, from one to five men were giving full time to JP field work.

5.1.2 Assistance to ComSubTrainPac and ComSubs7thFleet

In April 1944, ComSubTrainPac called a conference at Pearl Harbor to discuss plans for expanding sonar training in line with the growing importance of submarine sonar. Representatives of Division 6 were invited to participate in this conference. It was decided that immediate steps should be taken to set up basic and refresher courses for sonar operators and maintenance men at Pearl Harbor under ComSubTrainPac, and a refresher course at Perth, Australia, under ComSubs7thFleet.

The engineering staff of the CUDWR laboratory and the BuShips Field Engineering Group were called upon to assist ComSubTrainPac in planning the layout of a sonar training barge and in supervising its construction and the installation of equipment. When completed in the fall of 1944, this barge became the center for all sonar training at Pearl Harbor.

Meanwhile, Navy instructors had been selected for the Pearl Harbor project and sent to New London for special training. In June, a four-week course for these instructors was started at the CUDWR laboratory. During the first two weeks, instruction was given on submarine sonar operation and maintenance, followed by underway drill aboard submarines. In the last two weeks, emphasis was on effective methods of teaching, the use of training aids, and the planning of course curricula. Concluding sessions were devoted to practice teaching and to the planning of curricula for the courses to be given at Pearl Harbor.

Members of the New London training group accompanied the Navy instructors to Pearl Harbor and assisted them in getting the new courses started. Classes in sonar operation and maintenance began on the barge at Pearl Harbor in September 1944.

An officer and three enlisted men who were to give sonar refresher courses at Perth also attended the four-week course at New London. Training aids and instructional supplies were assembled and shipped. Sonar instruction, given principally during underway exercises, was begun at Perth in September 1944.

5.1.3 Assistance to ComSubsLant

In August 1944, a program for basic and refresher sonar operator instruction was initiated by ComSubsLant as part of the precommissioning training of new construction crews at New London. In addition, brief courses on the latest sonar developments were established for communications officers and for prospective commanding officers.

A former net tender was obtained by ComSubsLant for conversion into a sonar-radar training barge similar to the one being outfitted by ComSubTrainPac. The CUDWR laboratory assisted in planning the arrangement of training facilities on the barge, supervised the remodeling work, designed and manufactured special monitoring equipment, and aided in the installation of standard equipment modified for training purposes.[18]

The CUDWR training group, in collaboration with Navy personnel, developed an integrated training program designed to make full use of all facilities. A two-week course was planned, the first to include classroom instruction and procedure drill on standard sonar equipment installed on the piers at the Submarine Base, the second week to be spent in advanced instruction on the sonar-radar barge anchored in Long Island Sound. For the barge training, a target boat was equipped to play recordings of various ship sounds through an underwater projector.

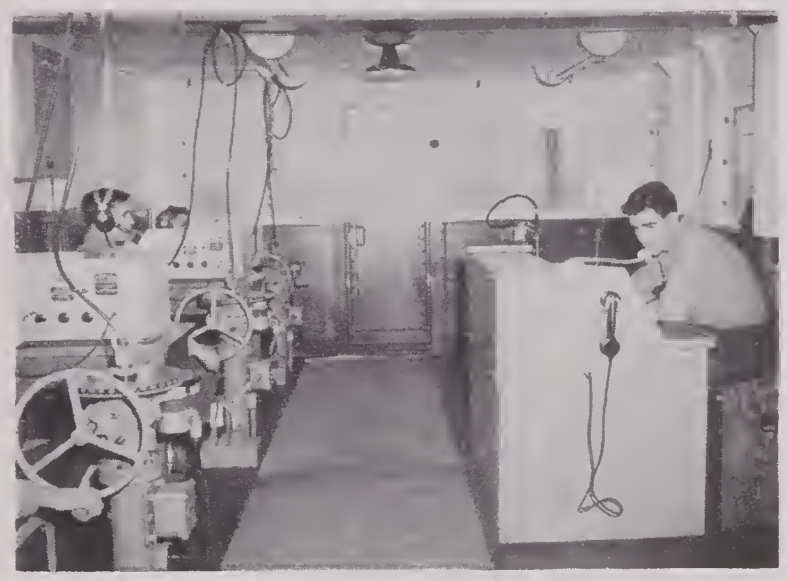
FIGURE 2. Group listening teacher in operation.

Facilities on the barge for sonar instruction included two rooms containing the same JP and WCA equipment as the submarine forward torpedo rooms, two WCA drill rooms, two JP drill rooms, a classroom, and a lookout station. An instructor's control console was provided for each of the JP drill rooms (see Figure 2). From the console one instructor could monitor several JP stations. Other later equipments were installed on the barge as they became available.

Sonar classes were started on the barge in January 1945; instruction ashore had begun somewhat earlier.

5.1.4 Operator and Officer Training at WCSS

In October 1944, a committee appointed by COMINCH made a survey of submarine sonar training at New London. On the basis of this survey the committee recommended that a basic course for submarine sonar operators be established at the West Coast Sound School, San Diego [WCSS]. It also recommended that 20 per cent of the officer graduates of the Submarine School, New London, be sent to San Diego for special training in submarine sonar operation and tactics. Both officers and men were to attend the Submarine School radar operator's course before going to San Diego.

The adoption of this plan gave an opportunity for the development of entirely new programs of sonar operator and officer instruction. Representatives of the CUDWR and UCDWR training groups collaborated with the instructional staff of WCSS in planning the new courses. Lesson plans were made for lectures and drill sessions; tentative lectures were written; objective-type written examinations and performance check lists were prepared; training aids were systematically assembled.

Two new synthetic trainers, the *group listening teacher* and the *sound recognition group trainer* [SRGT], were made ready by the UCDWR laboratory. The group listening teacher (see Figure 3) provided an automatic problem generator and a central console for monitoring 8 JP, 5 WCA, and 4 WEB equipments each enclosed in a sound-treated booth. Behind this quickly constructed group listening teacher was a long history of development by the UCDWR laboratory. Originally, *primary listening teachers* somewhat similar to the

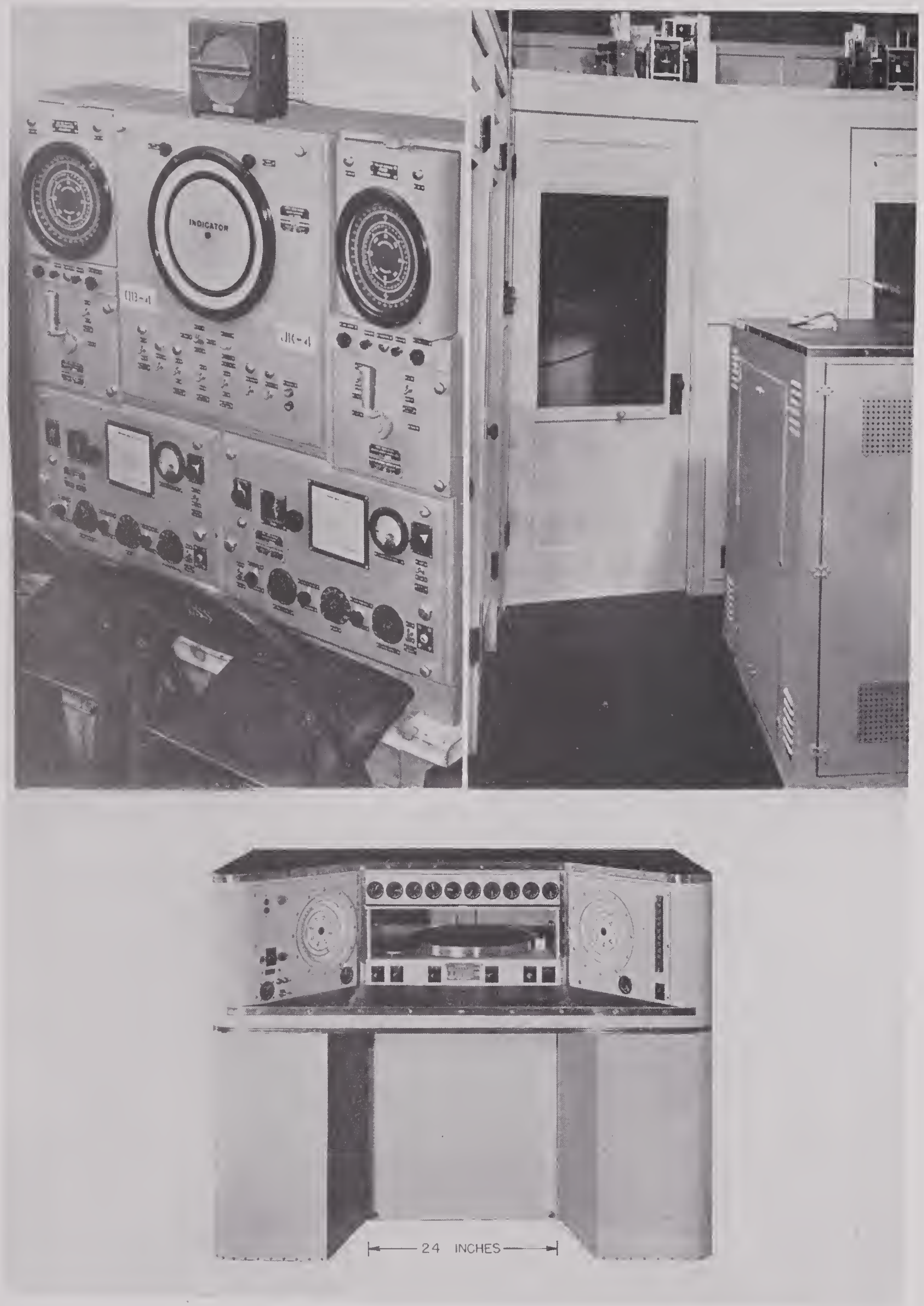
INDICATOR
QB-4
JK-4
24 INCHES

FIGURE 3. Group listening teacher.

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primary bearing teachers had been provided in quantity, but these were useful only for instruction in elementary procedures. An experimental model of an *advanced listening teacher* had been completed during the summer of 1944. The unique problem generator of this device was modified for use with the group listening teacher.

The sound recognition group trainer was a direct adaptation of the *echo recognition group trainer* [ERGT] used in ASW operator training. Recordings of sounds picked up over submarine listening gear were made into a series of drills, graded in difficulty. Each student's responses to the drill items were recorded on a web of paper at the central console from which the instructor directed the drills. Tests in turn count estimation, faint contact detection, target identification, and other auditory discriminations provided reliable objective scores of student performance in this essential phase of sonar operation. The SRGT drills and tests formed an important part of the training course for submarine sonar operators.

Instruction in submarine sonar was started at WCSS in November 1944. The course for operators was four weeks in length, three weeks ashore and one week underway on submarines which were operating with the ASW training vessels. The officers' course was limited to two weeks ashore. At a later date the operators' course was extended to five weeks.

5.1.5 Sonar Maintenance Training, Submarine School

In line with the recommendations of the COMINCH committee work was also begun on the establishment of a maintenance training course at New London. As a first step, an officer experienced in ASW sonar maintenance training was transferred to New London from the Fleet Sound School, Key West [FSS]. The CUDWR training group worked with this officer in planning training facilities, installing equipment, and planning a curriculum for the new course. Individual instructors were also given assistance in the preparation of lesson plans.

In order to simulate equipment casualties, trouble injectors were designed and built by the CUDWR laboratory. By throwing appropriate switches instructors were able to set up a series of trouble-shooting problems.

The maintenance course was four weeks in length; it was an advanced course designed for radio technicians who already had basic electronics training. Emphasis was placed on laboratory work, each student spending approximately 50 per cent of his time working with standard sonar equipment (see Figure 4). Maintenance instruction was started in January 1945.

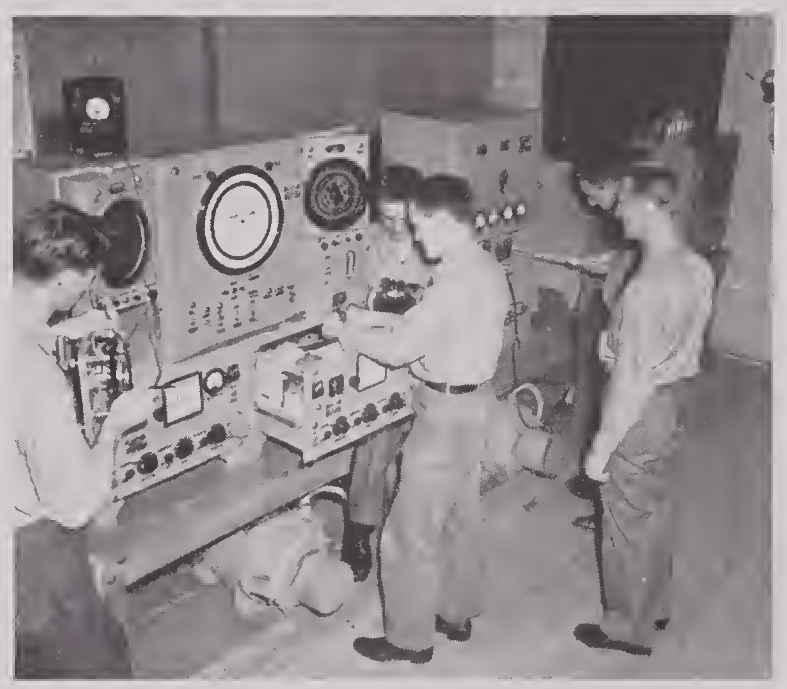


FIGURE 4. Standard sonar equipment.

5.1.6 JT, NLM, TDM, DCDI, and DCRE Training

In addition to giving assistance in the establishment of complete sonar training courses, the Division 6 training group, during 1944 and 1945, prepared instructional material for a number of sonar equipments developed by division laboratories. Instruction in use and maintenance of these equipments was added to the curricula of existing courses. In each instance, instruction books and other training aids were prepared for distribution with the first production units of the equipment.

For JT sonar, operator and maintenance

manuals, lantern slides, and lecture outlines were prepared. No new phonograph recordings were needed, since the sounds heard over JT and JP were virtually identical.

For the Noise Level Monitor [NLM], a synthetic trainer (see Figure 5) was developed to permit separate recordings of submarine machinery sounds and of background water noise to be played through a control panel into a monitor unit attached to a JP amplifier. At the control panel relative levels could be adjusted to simulate the sounds heard over each of the four NLM hydrophones aboard a submarine. Operation on this trainer closely simulated the conditions of using NLM at sea. Other instructional materials included a set of recordings to be used with the trainer, a wall chart, manuals for operators and maintenance men, and lesson plans for instructors.

For TDM equipment, the *range recorder teacher* [QFL] was modified by the substitution of standard bearing recorders as used in the *torpedo detection modification* aboard submarines. Five or more recorders were attached to a single central unit. Recordings of torpedo sounds produced characteristic recorder traces as well as the accompanying sounds. The device was given the Navy designation QFM. Instruction manuals for TDM operators and maintenance men were also prepared.

DCDI and DCRE required no operating instructions. Booklets explaining the use of these devices and maintenance manuals were written. Lantern slides and lesson plans for classroom use were prepared.

Throughout 1944 and early 1945, lectures on all of these new laboratory developments were given periodically by the CUDWR staff to prospective commanding officers, communications officers, and Navy instructors.

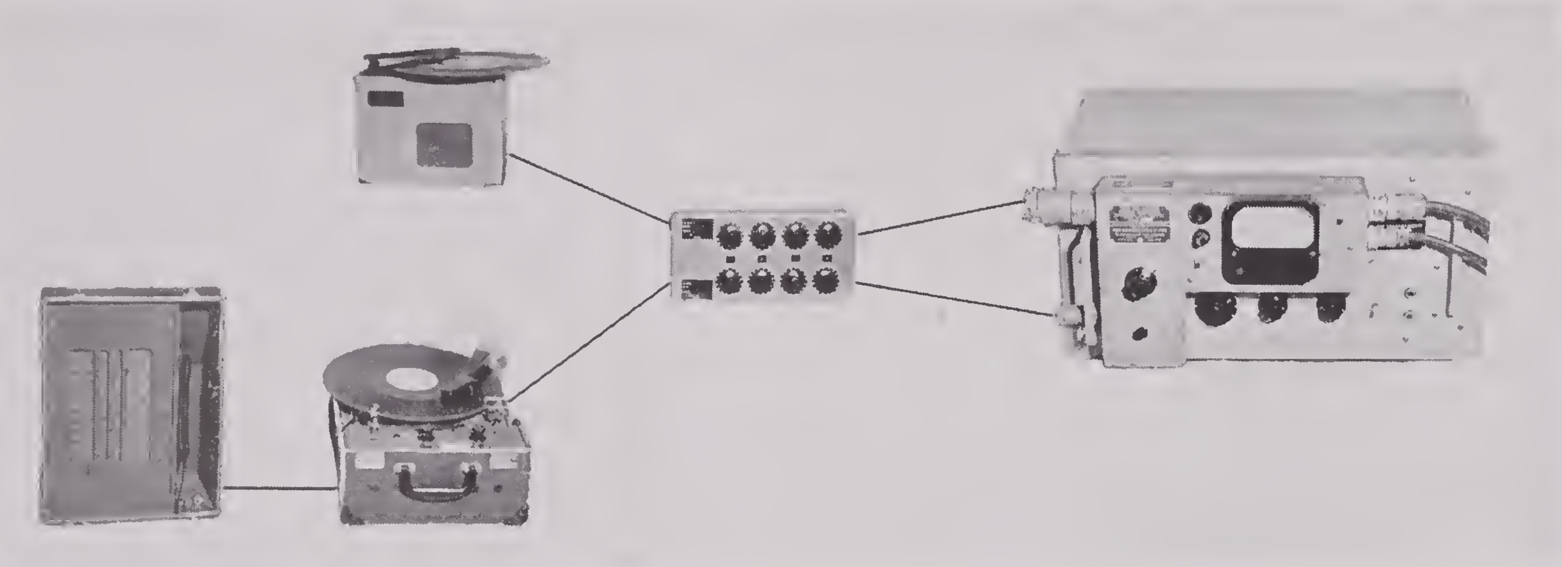


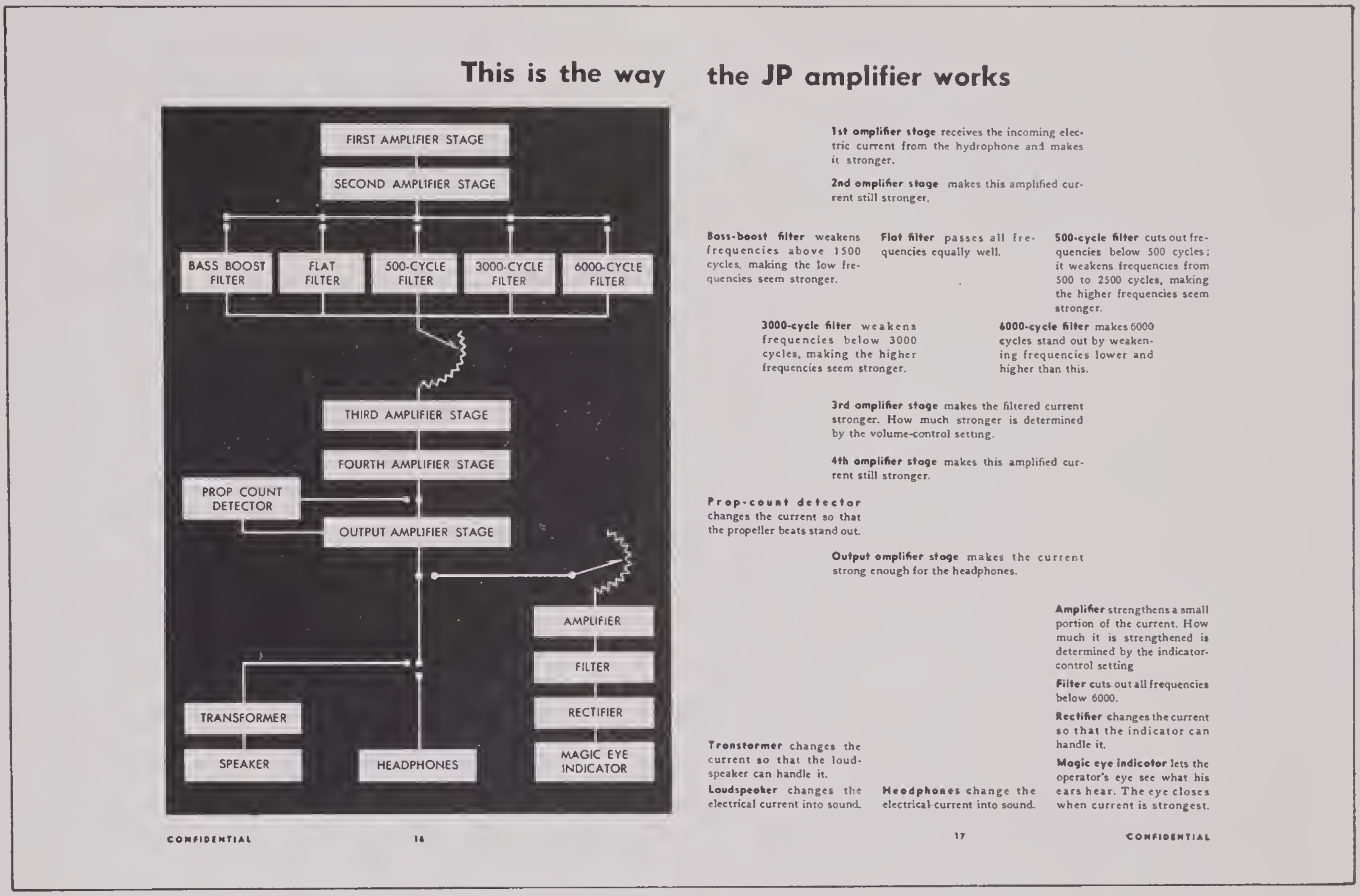
FIGURE 5. Noise level monitor components.

5.1.7 General Sonar Training Aids

Several additional training aids which have not been mentioned played a part in the sonar training programs. The *Submarine Sonar Operator's Manual* (NavPers 16167), written by the training group, was printed and distributed by BuPers to all training activities and all submarines. This manual (see Figure 6) presented for the first time standardized and officially accepted doctrines for sonic and supersonic searching and tracking and for single-ping echo ranging.

Paralleling the JP series of recordings, demonstration and drill recordings for WCA supersonic listening were developed by the training group and distributed in album form by BuPers. A set of experimental target-discrimination drill and test recordings, in which the student was required to pick out the designated target sound from other similar and confusing sounds, was completed and copies were made for experimental use at New London and San Diego.

A slide film on "Fundamentals of Sound" was produced for the Submarine School, New London. The film consisted of two 15-minute reels, each accompanied by a sound recording. Film and recordings were distributed by BuAer.



This is the way the JP amplifier works

1st amplifier stage receives the incoming electric current from the hydrophone and makes it stronger.

2nd amplifier stage makes this amplified current still stronger.

Bass-boost filter weakens frequencies above 1500 cycles, making the low frequencies seem stronger.

Flat filter passes all frequencies equally well.

500-cycle filter cuts out frequencies below 500 cycles; it weakens frequencies from 500 to 2500 cycles, making the higher frequencies seem stronger.

3000-cycle filter weakens frequencies below 3000 cycles, making the higher frequencies seem stronger.

6000-cycle filter makes 6000 cycles stand out by weakening frequencies lower and higher than this.

3rd amplifier stage makes the filtered current stronger. How much stronger is determined by the volume-control setting.

4th amplifier stage makes this amplified current still stronger.

Prop-count detector changes the current so that the propeller beats stand out.

Output amplifier stage makes the current strong enough for the headphones.

Amplifier strengthens a small portion of the current. How much it is strengthened is determined by the indicator-control setting

Filter cuts out all frequencies below 6000.

Rectifier changes the current so that the indicator can handle it.

Magic eye indicator lets the operator's eye see what his ears hear. The eye closes when current is strongest.

Transformer changes the current so that the loudspeaker can handle it.

Loudspeaker changes the electrical current into sound.

Headphones change the electrical current into sound.

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FIGURE 6. Pages from *Submarine Sonar Operator's Manual.*

5.2 RADAR TRAINING PROGRAM

In October 1944, CUDWR received a request from the Submarine School at New London for assistance in establishing a course for submarine radar operators. The CUDWR training group in turn asked the Applied Psychology Panel, NDRC, to collaborate in fulfilling this request, since members of the Panel's project SC-70, NS-146, had had considerable experience in planning training courses for surface craft radar operators.

Together the two groups planned the course curriculum, developed lesson plans, outlined drill schedules, and trained the Navy instructors assigned to the school. They worked with the instructional staff in the preparation of lectures, objective-type examinations, and check lists for evaluating student performance. Various minor training aids were also developed.

The radar operator course was started in December 1944. A member of the training group continued to work with the course instructors for several months. The curriculum was revised to meet deficiencies which appeared, additional work was done on performance tests in an effort to obtain accurate measures of operating skill, and a preliminary instruction book on fundamentals of radar was written.

5.3 VOICE COMMUNICATIONS PROGRAM

In April 1944, the CUDWR training group was asked by ComSubsLant to assist in the development of a training program designed to improve voice communications on submarines.

The aid of two other NDRC groups which were experienced in the field of voice communications was obtained. These groups were the Psycho-Acoustic Laboratory, Harvard University, Division 17, Section 17.3, and Project N-109 Psychological Corporation, Applied Psychology Panel.

In order to best fulfill the request made by ComSubsLant, a two-fold program was planned: first, the standardization of phraseology and procedures used in voice communication; second, the establishment of training courses for officers and men.

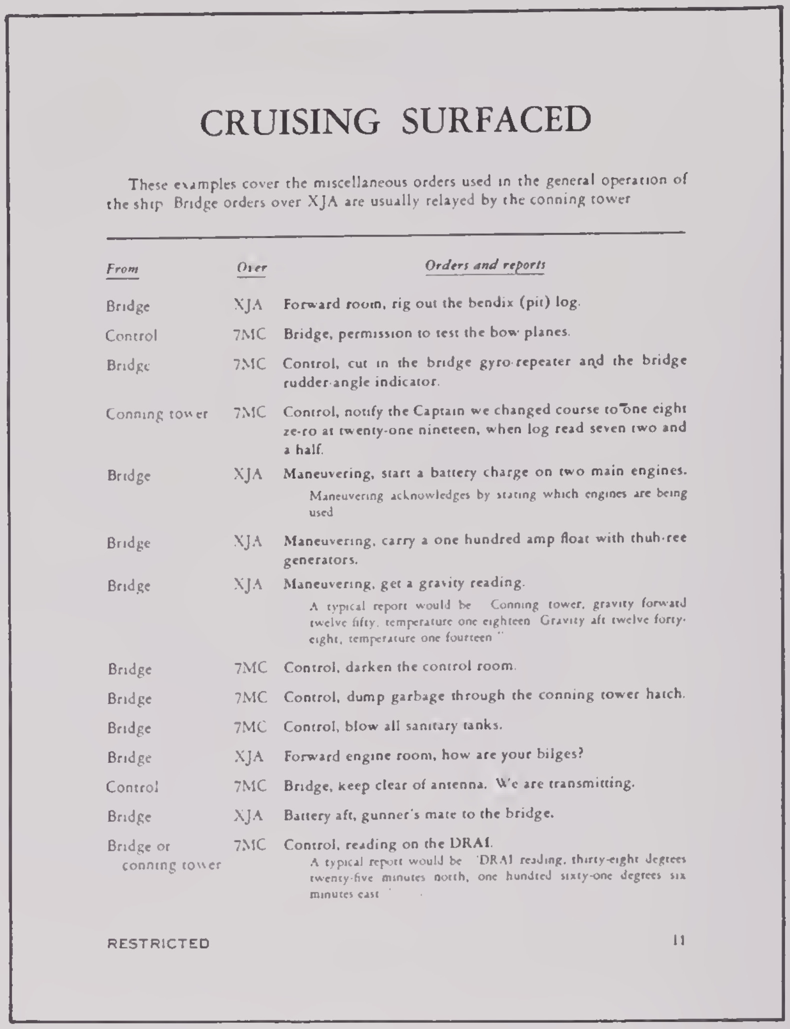
5.3.1 Standardized Phraseology

To accomplish the first part of this program, a catalogue was made of alternative forms of all commands and reports in common use. These were arranged according to the ship's operations involved. Experimental tests were then conducted to determine the relative intelligibility of the alternative forms; these tests were made using sound-powered telephone equipment in the presence of masking noise designed to reproduce the noise ordinarily present during operations on board a submarine. On the basis of the experimental tests and conformity with submarine usage, detailed uniform voice procedures and specific wordings for all important submarine commands were prepared. These were submitted for criticism to officers throughout the submarine service and, with slight revisions, were compiled in a booklet entitled *Standard Submarine Phraseology* (see Figure 7), copies of which were distributed by ComSubsLant to all submarine activities.

5.3.2 Training Courses

The development of the training program proceeded concurrently with the work on standardization of phraseology and procedures. A basic course for enlisted men and officers was outlined, a training room was planned, standard submarine communication equipment was procured, additional equipment needed for the training room was designed and constructed, and various training aids were prepared. The first training room (see Figure 8) was set up and a basic course was started in May 1944 at the New Construction Training School, New London.

In June 1944, a program of training at three levels was approved by ComSubsLant. This program included a basic course in the fundamentals of telephone talking, an intermediate course emphasizing the procedures and phraseology for each station, and an advanced course covering coordination of voice communications by the combat team.



CRUISING SURFACED

These examples cover the miscellaneous orders used in the general operation of the ship Bridge orders over XJA are usually relayed by the conning tower

From	*Over*	*Orders and reports*
Bridge	XJA	Forward room, rig out the bendix (pit) log.
Control	7MC	Bridge, permission to test the bow planes.
Bridge	7MC	Control, cut in the bridge gyro-repeater and the bridge rudder-angle indicator.
Conning tower	7MC	Control, notify the Captain we changed course to one eight ze-ro at twenty-one nineteen, when log read seven two and a half.
Bridge	XJA	Maneuvering, start a battery charge on two main engines. Maneuvering acknowledges by stating which engines are being used
Bridge	XJA	Maneuvering, carry a one hundred amp float with thuh-ree generators.
Bridge	XJA	Maneuvering, get a gravity reading. A typical report would be Conning tower, gravity forward twelve fifty, temperature one eighteen Gravity aft twelve forty-eight, temperature one fourteen "
Bridge	7MC	Control, darken the control room.
Bridge	7MC	Control, dump garbage through the conning tower hatch.
Bridge	7MC	Control, blow all sanitary tanks.
Bridge	XJA	Forward engine room, how are your bilges?
Control	7MC	Bridge, keep clear of antenna. We are transmitting.
Bridge	XJA	Battery aft, gunner's mate to the bridge.
Bridge or conning tower	7MC	Control, reading on the DRAI. A typical report would be 'DRAI reading, thirty-eight degrees twenty-five minutes north, one hundred sixty-one degrees six minutes east '

RESTRICTED 11

FIGURE 7. Page from *Standard Submarine Phraseology.*

In September 1944, COMINCH approved the extension of the Voice Communications Training Program to six other submarine training activities in addition to the New Construction Training School and Submarine School, New London. These were Portsmouth, San Diego, Hunter's Point, Mare Island, Pearl Harbor, and Midway.

Officers who had had experience in teaching speech were obtained to serve as head instructors at each of the six places. These officers and a group of enlisted men were trained at New

London by the NDRC groups and the Medical Research Department, the latter having been put in charge of all voice communication training at the Submarine Base, New London.

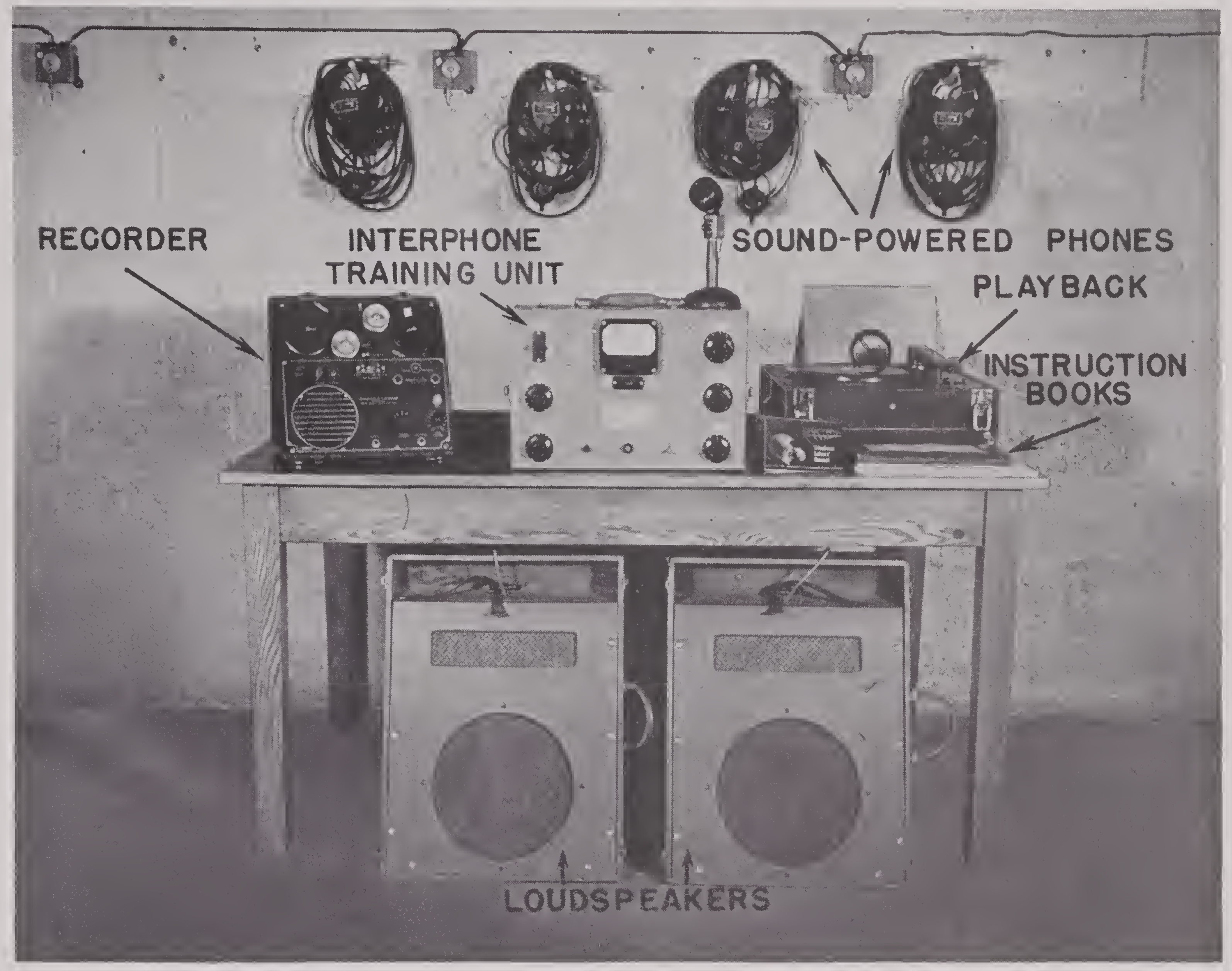


FIGURE 8. Training room equipment.

5.3.3 Training Aids

A number of training aids and devices were prepared for use in the voice communication instruction. These included the following:

1. *Standard Telephone Talkers' Manual*, a basic text on submarine voice communication procedures.

2. *Standard Submarine Phraseology*, a booklet giving voice procedures and phraseology recommended as standard for all submarine voice communication.

3. *Ship's Organization Chapter on Voice Communications* (to be inserted in each ship's organization book), a brief description of submarine voice communication circuits, recommendations for manning stations, rules for correct operation of equipment, and outline of standard voice procedures.

4. *Instructor's Handbook for Basic Course*, an outline of a basic course for officers and men, instructions for installation and maintenance of equipment in training rooms, drill material, record forms, and lecture notes.

5. *Wall charts*, a list of "Seven Rules for Telephone Talking" and "Pronunciation of Numerals."

6. *Submarine telephone talker training record*, a phonograph recording illustrating correct and incorrect voice communications during battle circuit drill.

7. *Training interphone*, an instrument de-

signed by the Psycho-Acoustic Laboratory for use with classroom drill circuits. The interphone included a noise generator, a meter for measuring level of speech, and a filter for distorting speech.

8. *Switch panel,* a central control mechanism for the instructor monitoring drill circuits.

Kits for completely equipping the training rooms were assembled at New London and distributed to the places where training courses were to be established. NDRC personnel assisted in the installation of equipment in the voice communication training rooms at New London, Portsmouth, and Pearl Harbor.

5.4 SUBMARINE BATHYTHERMOGRAPH PROGRAM

Bathythermographs [BT] were first installed on submarines in February 1942. From that time until the end of Division 6 activities in 1945, members of the Woods Hole Oceanographic Institution [WHOI] and of the University of California Division of War Research [UCDWR] assisted in training submarine personnel who used and maintained the BT equipment. This assistance was principally of two kinds, field instruction and preparation of training aids.

5.4.1 Instruction in the Field

At the start, assistance in submarine BT training was given incidentally by WHOI representatives who supervised installations of BT equipment. In July 1943, this assistance was formalized at the request of BuShips[a] and WHOI representatives were sent to the new construction training activities at New London, Portsmouth, and Manitowoc. They conducted general lectures to introduce the BT to large groups of submarine officers and men, gave intensive training to small groups of communications and diving officers ashore, and supervised instruction of officers during tests at sea.

In May 1944, a WHOI representative visited the submarine commands at San Diego, San Francisco, Pearl Harbor, and Midway. As a result of this survey, a WHOI representative was immediately assigned to ComSubTrainPac for training and field engineering work. A Navy officer, trained in use and maintenance of the submarine BT, was assigned to similar duties with ComSubs7thFleet at Perth, Australia.

Formal participation of UCDWR in submarine BT field training began in May 1944, when the Office of the Coordinator of Research and Development requested the establishment of a much expanded program in the application of oceanography to subsurface warfare. It was urged that additional civilian field representatives be furnished to assist submarine training commands in the Pacific.

Three men, trained in oceanography and in the installation, operation, and maintenance of the submarine bathythermograph, were furnished by UCDWR. From October 1944 until September 1945, these men gave instruction at various Pacific submarine training activities —Mare Island, San Diego, Pearl Harbor, and Guam. In the meantime, WHOI representatives continued to give BT instruction at submarine bases on the Atlantic Coast.

5.4.2 Training Aids

In March 1943, at the request of the Office of the Coordinator of Research and Development, WHOI and UCDWR jointly undertook the preparation of instruction manuals on the use of oceanographic data in relation to submarine warfare. By July they had completed the *Use of Submarine Bathythermograph Observation* (NavShips 943-F), which was printed by BuShips and widely distributed throughout the submarine force. In February 1944, a revision of the rules for predicting maximum sound ranges was finished, followed in March by a supplement to NavShips 943-F, *Use of the Bathythermograph as an Aid in Diving Operations* (NavShips 900,018). Both of these were published and distributed by BuShips.

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[a] The training activities of WHOI from this date on were supported by a direct contract between WHOI and BuShips. The work is mentioned here, however, to complete the picture of submarine bathythermograph training.

In May 1944, as part of the expanded program in the application of oceanography to subsurface warfare, UCDWR undertook the revision and supplementation of all existing BT instructional material. New material resulting from oceanographic research was added to that already published, and the whole presented in a form to insure better understanding of its operational significance.

A new edition of *Use of Submarine Bathythermograph Observations* (NavShips 900,069) was planned. It was to be issued in seven sections in a looseleaf binder, permitting later replacements and supplements. By August 1945, six of the seven sections had been completed; four had been printed and distributed by BuShips. A less technical pamphlet, *The Sea for Submarines* (NavShips 900,018) had also been written and distributed by this time.

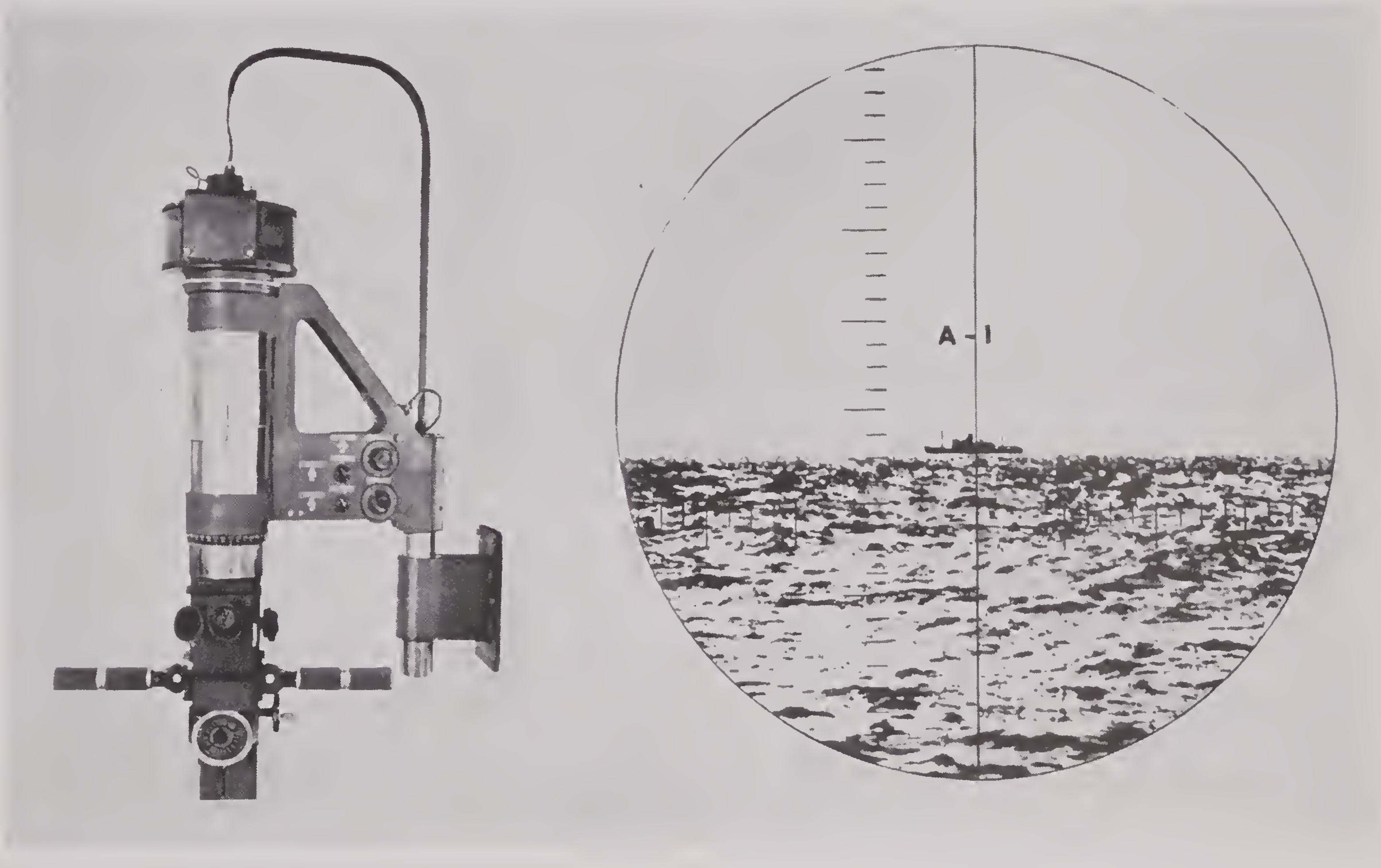

FIGURE 9. The periscope trainer. The trainer is shown at the left, and at the right is a representative field of view as seen in low power.

Meanwhile WHOI had prepared two publications for BT instructors. The first, an informal pamphlet, *Lecture Notes on Use of Submarine Bathythermograph*, was issued in January 1944. It was revised in 1945, with editorial assistance from the CUDWR training group. *The Reference Handbook for Submarine Bathythermograph Field Engineers* was issued to all BT instructors in November 1944.

5.4.3 Devices

Two submarine BT training devices were built by the UCDWR laboratory late in 1944. For SubRon 45, San Diego, the laboratory constructed one unit of a BT simulator to be attached to the Askania diving trainer. This attachment permitted simulated changes in buoyancy to affect diving operations on the trainer much as they would be influenced by temperature gradients at sea. A similar device was later procured by the Navy on direct contract. For WCSS, the laboratory built a classroom demonstrator. This consisted of a standard submarine BT with auxiliary attachments which enabled the instructor to reproduce any desired BT record by applying suitable changes in temperature.

5.5 WORK DONE ON SPECIAL REQUEST

A number of devices and training aids were produced by the CUDWR laboratory to fill specific requests of the Submarine School, New London.

The *periscope trainer* was designed to give officers elementary practice in ship recognition, judgment of angle-on-the-bow, and estimation of range by telemeter or stadimeter. The trainer had the general form and all of the standard controls of the lower part of a Mark IV periscope. Replacing the top of the periscope was a circular holder in which could be inserted film strips showing target ships at various ranges and angles-on-the-bow (see Figure 9). Simplified recognition charts were attached. The instrument could be used for self-instruction. After identifying the ship and estimating its angle-on-the-bow and range, the student could check the correctness of his answers by tilting the vertical sweep in low power until an answer box above the ship image became visible. Six periscope trainers were built at the laboratory and shipped early in 1945 to various Navy activities. The Navy later let a contract for the manufacture of 25 additional units.

Extensive modifications were made on the Mark I attack teacher at the Submarine School. In place of the single manually controlled target ship of the original model, the redesign permitted the use of five to seven target and screening ships automatically controlled by a modified Mark I TDC. A repeater unit which showed own-submarine's course and speed was installed in the conning tower. Another repeater unit in the classroom showed relative bearing, target speed, range, and angle-on-the-bow. Six additional modification units were built at the laboratory in 1944 and installed on attack teachers at other submarine bases. A sound injector to feed automatically controlled target propeller noise into the sound stack was designed as an adjunct to the attack teacher modification. One unit of the injector was installed at the Submarine School in the spring of 1945.

Five slide films for instruction in estimating angle-on-the-bow were made in 1944. Prints were procured and distributed by BuAer.

Negatives of 248 lantern slides for classroom use in the various departments of the Submarine School were prepared by the training group and turned over to BuAer for final processing. The majority of the slides were reproductions of wall charts and of diagrams from instruction books.

A method of making lantern slides with movable dials was developed and employed in the construction of three types of animated slides for teaching relative bearings, search procedures, and the use of the Is-Was. Seven units of each were furnished by CUDWR.

A large-scale model of the Mark VIII torpedo angle solver was constructed as a classroom aid for the Submarine School.

5.6 SUBMARINE TRAINING AIDS

Phonograph recordings, slides and films, and classroom teaching devices prepared by Division 6 are listed in Appendix III. A list of instruction books may be found in the bibliography.

Chapter 6

TRAINERS FOR ANTISUBMARINE WARFARE SONAR OPERATORS

In an early report of the NDRC Committee on the Selection and Training of Sound Operators, the need was expressed for devices which would afford training in the various constituent skills required of sonarmen. In the case of surface craft sonarmen, the ability to keep the QC projector directed on a moving target and accurately report its bearings is probably of first importance. It is essential that this routine become practically automatic, and yet it is one of the most difficult to master. Special attention was therefore given to the development of trainers providing drills in echo-ranging search and target-bearing reporting.

The first trainer which was designed and developed as part of the program for the training of surface craft sonarmen was the bearing teacher. This device was so complex in construction, however, that production in quantity was too slow. Because of this disadvantage it was necessary to develop a more elementary type which could be produced quickly in quantity. This later design was known as the *primary bearing teacher* [PBT]. The original trainer was then designated *the advanced bearing teacher* [ABT]. Later, after the *bearing deviation indicator* [BDI] had been perfected and put into operational use, an auxiliary BDI training unit (OTE-8) for attachment to the ABT was designed. A more compact version of the PBT, small enough to be carried by hand aboard ship or at advance posts where classroom facilities might have to be improvised, was likewise developed. This was designated the *midget bearing demonstrator* [MBD].

All these early trainers served to train only one student at a time. This was a serious drawback, since it tied up the time of the instructor as well as the trainer. In the later phases of the training program, the principles of the individual trainers were adapted and applied to a series of group trainers, in which a number of student practice stations could be directed and monitored by a single instructor simultaneously. Since these group trainers were the most effective and economical in terms of time of all the elementary training devices, and since they would undoubtedly be the point of departure for any future elementary training program, they are described in some detail here. The earlier, individual trainers are not covered, but the interested reader will find references to microfilmed material on all of them in the bibliography for this chapter. The advanced bearing teacher in particular did yeoman service in refresher drills aboard training ships where there was not space enough for larger installations.

One of the first and simplest of the group trainers developed is the *echo recognition group trainer* [ERGT], used for the sole purpose of teaching discrimination among underwater sounds. This device is described first. *Operator training equipment, Models 2 and 10* [OTE-2 and OTE-10], is then discussed. Although OTE-2 is an individual operator trainer, it is included because it forms the basis for the proposed OTE-10, which would provide target bearing, range, and doppler inputs to five or more sonar practice stacks simultaneously. An account is then given of the BDI trainer, developed to serve as an adjunct to either ABT or the Sangamo attack teacher and later adapted to and incorporated in the group operator trainer. Proceeding in order of increasing complexity, the group operator trainer is described last.

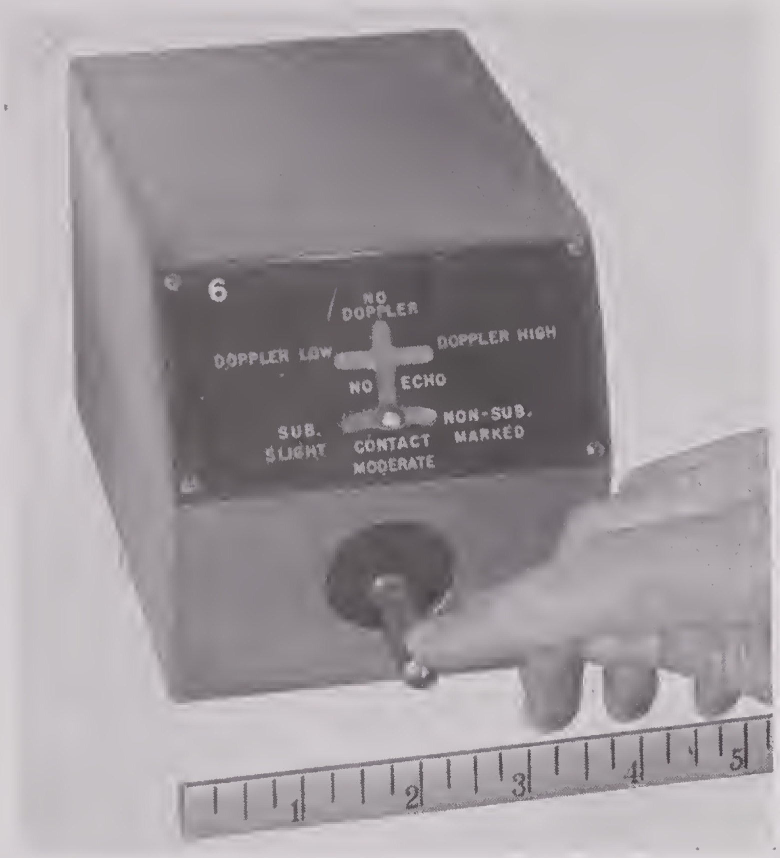
6
NO DOPPLER
DOPPLER LOW
DOPPLER HIGH
NO ECHO
SUB. SLIGHT
CONTACT MODERATE
NON-SUB. MARKED
1
2
3
4
5

FIGURE 1. Station key for echo recognition group trainer.

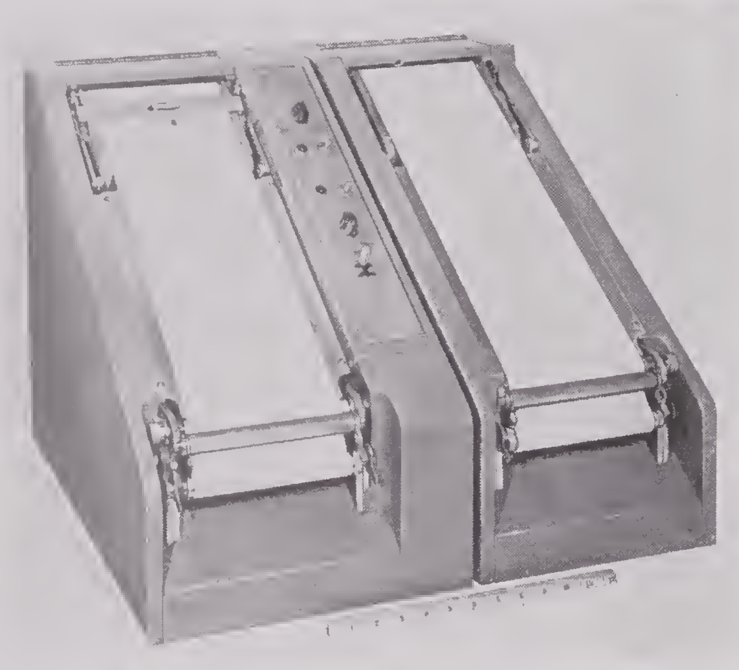

FIGURE 2. Echo recognition monitor recorder (combination of type A and B units).

Echo Recognition Group Trainer

The echo recognition group trainer [ERGT] is used to drill and test students, simultaneously at numerous individual stations, in analysis of underwater sounds. The equipment includes phonograph recordings of actual sea echoes and reverberations, student stations with manually operated station keys, and an instructor's station. The station key at each student post has seven positions which permit the student to report his findings to an echo recognition monitor recorder at the instructor's station. This echo recognition monitor recorder consists of a group of station keys and one recorder. The latter may be the Model II type A, shown on the left of Figure 2, or a combination of type A and type B. The instructor follows the visual reports as they show on the recorder and thus is enabled to check continuously on each man's judgment of the echoes and to point out the errors made. This training device was developed by UCDWR.

6.1 STATION KEY DESCRIPTION

The station key has seven positions, as shown in Figure 1. Each key is connected to three styli in the monitor recorder and to the two voltage sources indicated in Figure 3. Position *X* is the normal or "no echo" position, at which all three styli have zero voltage and do not operate.

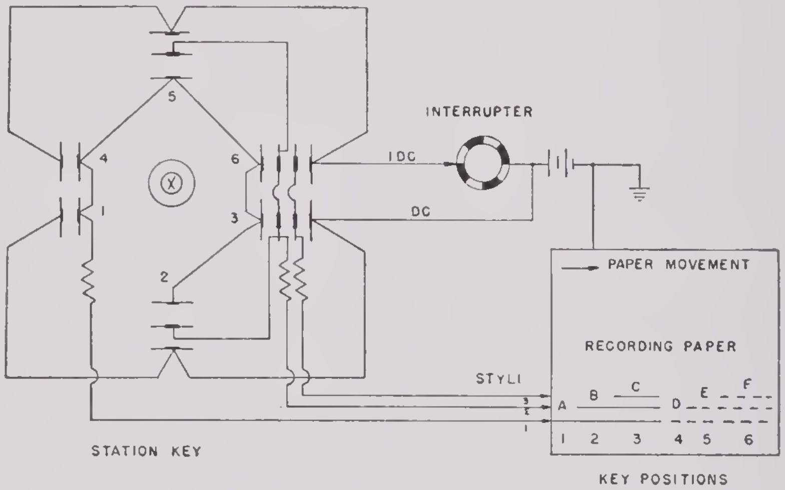
5
4
1
X
6
3
2
INTERRUPTER
IDC
DC
PAPER MOVEMENT
RECORDING PAPER
STYLI
3
2
1
A
B
C
D
E
F
1
2
3
4
5
6
STATION KEY
KEY POSITIONS

FIGURE 3. Schematic diagram of marking circuit.

When the station key is moved to position 1, a steady d-c voltage is applied to stylus 1 and a solid mark is recorded as shown at *A*. When the station key is moved to position 6, an interrupted d-c voltage is applied to styli 1, 2, and 3, thus marking the recorder paper as shown at *F*. The type of markings recorded at the intermediate key positions 2, 3, 4, and 5 are likewise illustrated in the figure.

The six marking positions of the station key may be used as desired to make any of six differently indicated reports to the instructor. As Figure 1 shows, double meanings were assigned to the three lower positions. In any given exercise, the character of the recorded material and the sequence of reporting determined which of the double meanings were used.

The station key is operated by moving the handle. The handle in turn moves the white target spot fastened through the plate to the key shaft. When the handle is released, the target spot returns to the "no echo" position.

6.2 TANK AND PAPER DRIVE ASSEMBLY

The tank and paper drive assembly is the standard design used in the Sangamo range recorder, except that its length has been extended by setting the drive roll farther from the tank.

The a-c paper drive motor operates at approximately 1,750 rpm through two sets of reduction gears to drive the paper roll at the front of the recorder. The motor and high-speed reduction gears are mounted on Lord mounts to reduce motor noises. This set of reduction gears connects with a flexible coupling to the low-speed set of reduction gears. The paper drive roll causes the recording paper to travel 15½ in. per minute. At the right end of the drive roll (see Figure 4) is an additional spring coupling which drives the Type B unit if the latter is attached.

The styli are mounted in a phenolic bar, each soldered tightly in one of the metal tubes. A set screw holds each stylus in place and provides a means of adjustment to give uniform paper pressure and uniform marking. (The intensity of marking on the paper depends somewhat on stylus pressure.) The stylus bar is held in place on the tank assembly by steel pins which also serve as the axis of rotation for the stylus bar. The push-bar assembly operates on the arm to hold proper stylus pressure when the recorder tank is closed. However, when the tank is opened to change paper, the push bar slides back so that the stylus assembly can be tilted to raise the styli.

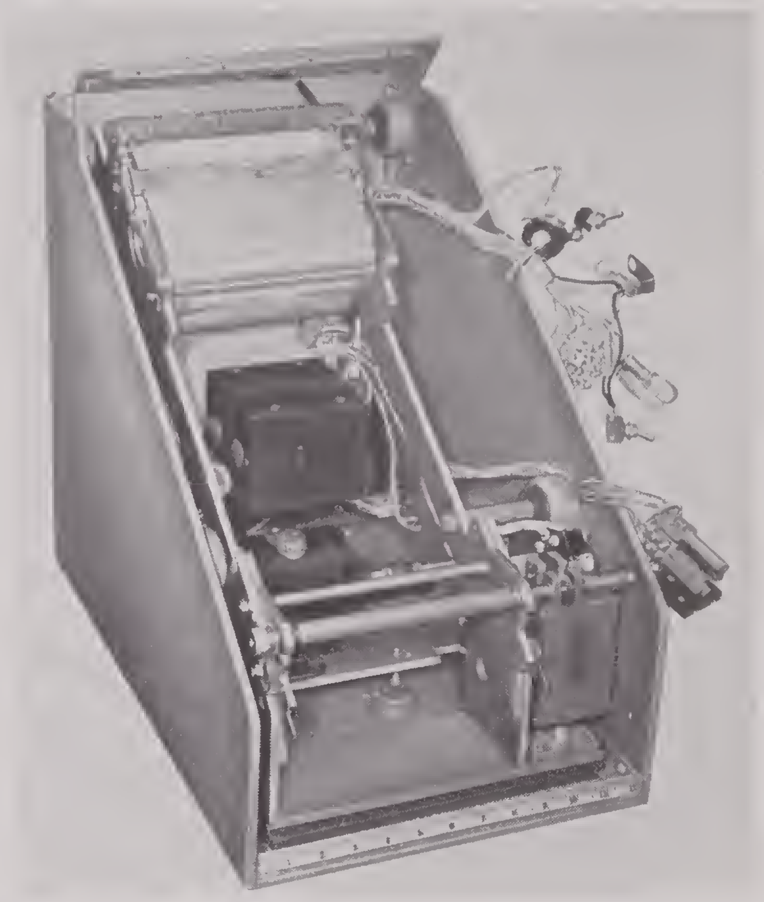

FIGURE 4. Type A monitor recorder, interior view.

6.3 ELECTRIC CIRCUITS

Steady and interrupted d-c voltages are supplied to each station through the Cannon plug terminal. These voltages are returned from each station key to the marking styli. The value of the marking voltage may be adjusted by the sensitivity potentiometer, R-103, which varies the a-c voltage supplied to the rectifier unit. Three circuits to operate the monitor recorder include (1) a step-down transformer which delivers 6.3 volts of alternating current to two selenium rectifiers, thus providing the d-c power to the styli for marking (the three styli terminals are connected to the key contacts through 1,000-ohm resistors); (2) a circuit which supplies power to a 110-volt, 60-c motor that may be silently turned off or on by means of a lever-operated microswitch; and (3) a power circuit which furnishes 110 volts to the electric heaters for the plates which dry the paper.

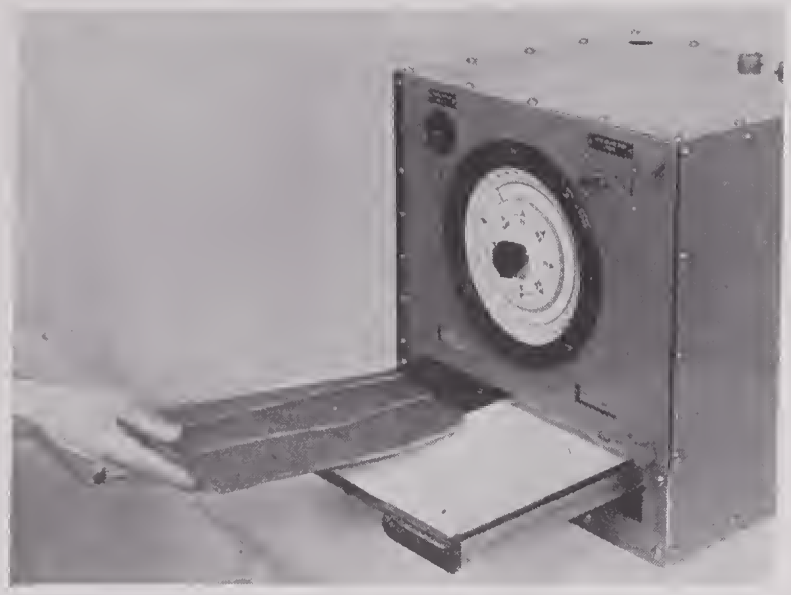

FIGURE 5. Inserting program cam in mechanical unit.

Operator Training Equipment—Models 2 and 10

Operator training equipment, model 2 (OTE-2) is a device which provides target information inputs to a sonar stack to aid in training an individual sonar operator to "hold" a target throughout an attack run. The proposed OTE-10 provides similar inputs to five or more stacks simultaneously, thus requiring only one instructor for several operators. The signals are generated by an electronic unit and controlled in range, doppler, and bearing effects by program records inserted in a mechanical unit. Readings on the front panel of the mechanical unit indicate student performance. Both devices were developed by HUSL.

6.4 INTRODUCTION

Operator training equipment in general was an outgrowth of the attempt to supply artificial signals for use in testing sonar gear. Such test signals, as they were perfected, were quickly applied in the training field, since they constituted a means of duplicating certain operational conditions in the classroom.

6.5 TECHNICAL DEVELOPMENT

In the early phases of the development of artificial signals for testing purposes, various methods of producing signals were tried. The first was an attempt to play phonographically recorded reverberation with an electric pickup and then to feed the signals through proper circuits into sonar gear under test. This method proved unsatisfactory because of the difficulty in recording and reproducing the high frequencies found in reverberation. An attempt was then made to generate an accurate simulation of the reverberation signal by electronic means. To do this a noise generator was developed in which the noise signal produced frequency modulation of an oscillator whose output was fed to a receiver in such a manner that the signal intensity decreased with time. Since this effect was the reverse of normal *time-varied gain* [TVG], in which the gain increases with time, it was given the name of inverse time-varied gain. When the proper bandwidths were determined, this arrangement gave a fair imitation of the reverberation signal. Simple keying circuits were then developed by means of which ping and echo signals could be injected when desired.

It was then suggested that phase modulation might give more accurate reverberation simulation, and two *simultaneous lobe comparison* [SLC] demonstration units were developed to provide phase-modulated echo and reverberation signals. These devices were equipped with manual control of the phase shift of the echo to give left-right indications, and with electronic control of the random phase variation of reverberation.

Later an arrangement of projector simulator coils was incorporated as an improvement in the SLC demonstration unit. These coils had been developed as part of the *artificial projector* (see Chapter 11) but proved valuable in a number of other applications involving phase modulation, including several OTE equipments in addition to the models discussed in this section. The projector simulator coils comprised essentially an exciter coil, fed with keyed signal current, that was moved manually in accordance with the bearing deviation, over three secondary coils. The output of these coils was properly phase- and amplitude-modulated to simulate the output of a projector and could be fed directly into a BDI to give indications just like those obtained from an actual projector operating under service conditions. At this stage of the

OTE-2 development, the coils were used only for echo generation, since reverberation and noise were still being provided electronically.

The next step was to use projector simulator coils to produce the reverberation as well as the echo, since electronically generated reverberation was found to produce an unsatisfactory image on the BDI screen. In this form, the OTE-2 was an automatic motor-driven attack simulator that would deliver reverberation signals and echo signals similar to those obtained in actual service for time variation of target range, bearing, and echo doppler.

In the device in its final form, it was planned to control the variation of echo and reverberation by means of rotary program cams. Rectilinear cams were substituted, however, because they made it possible to use easily changeable "program records" by means of which signals could be supplied simulating those of previous actual attacks on submarines, and also to include in the device a simple mechanism to record permanently the operator's performance in following the ship's course during the attack.

When operated aboard ship at dockside it was found that the reverberation-producing part of OTE-2 could be turned off and the natural reverberation used quite satisfactorily. When the ship was under way, however, the problem of locking in echo doppler with the reverberation proved very troublesome.

6.6 GENERAL DESCRIPTION OF OTE-2

Two units make up the main body of OTE Model 2, one of them electronic, the other mechanical. Auxiliary equipment consists of a cabinet in which 24 program records and all necessary connecting cables can be stored. Functional connections between the OTE-2 and the standard sonar gear are shown in Figure 6.

The electronic unit, a circuit diagram of which is shown in Figure 7, produces the essential frequencies of the echo and reverberation signals and may be keyed either by the sonar stack or by a keying circuit in the mechanical unit. The latter method is used when the device is combined with a mockup stack rather than with an actual shipboard installation.

The artificial reverberation, which has inverse TVG, is controlled in frequency for own doppler by the mechanical unit and is modulated at random in both amplitude and phase. The signal, after it is generated in the electronic unit, is controlled by the mechanical unit in its range, own doppler, target doppler, and bearing, and in accordance with the projector's beam pattern. The control includes the phasing effect that is found in a split projector like that employed with BDI.

When the OTE-2 equipment is used with BDI, the beam pattern is so controlled that audible echoes and center indications are obtained when the operator trains to the proper bearing; and the proper audible and visual signals are received for any bearing that deviates slightly from the center bearing of the target. No echo is received, however, when the deviation between true target bearing and the bearing that the operator has determined is so large that an actual echo would not be received.

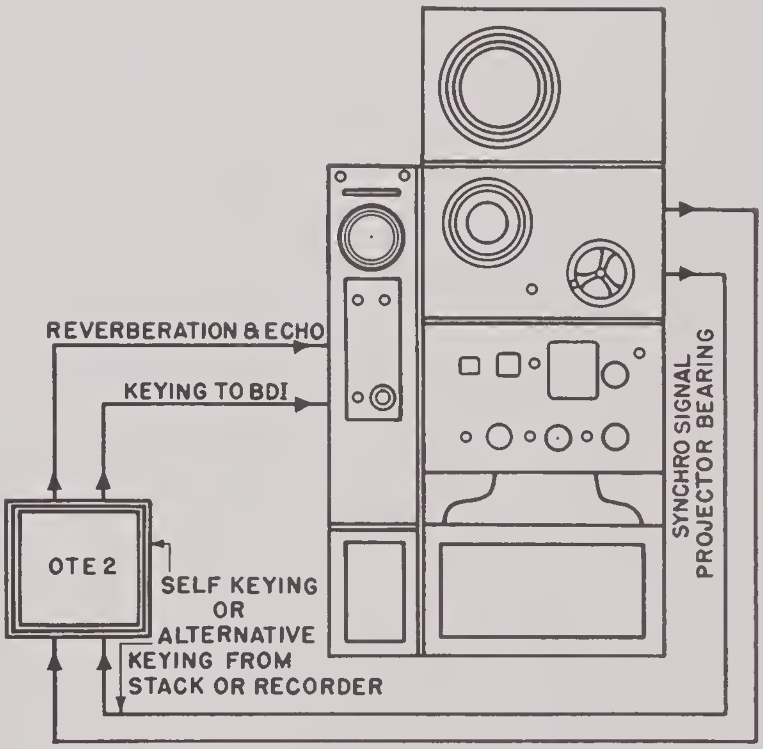
REVERBERATION & ECHO
KEYING TO BDI
OTE 2
SELF KEYING OR ALTERNATIVE KEYING FROM STACK OR RECORDER
SYNCHRO SIGNAL PROJECTOR BEARING

FIGURE 6. Block diagram—OTE-2 in relation to sonar gear.

The mechanical unit, shown in Figure 5, is in front of the instructor during the training period. The standard sonar bearing dial on the front panel has two indicators; one is the usual "bug" showing actual projector bearing; the other is a narrow pointer that indicates target

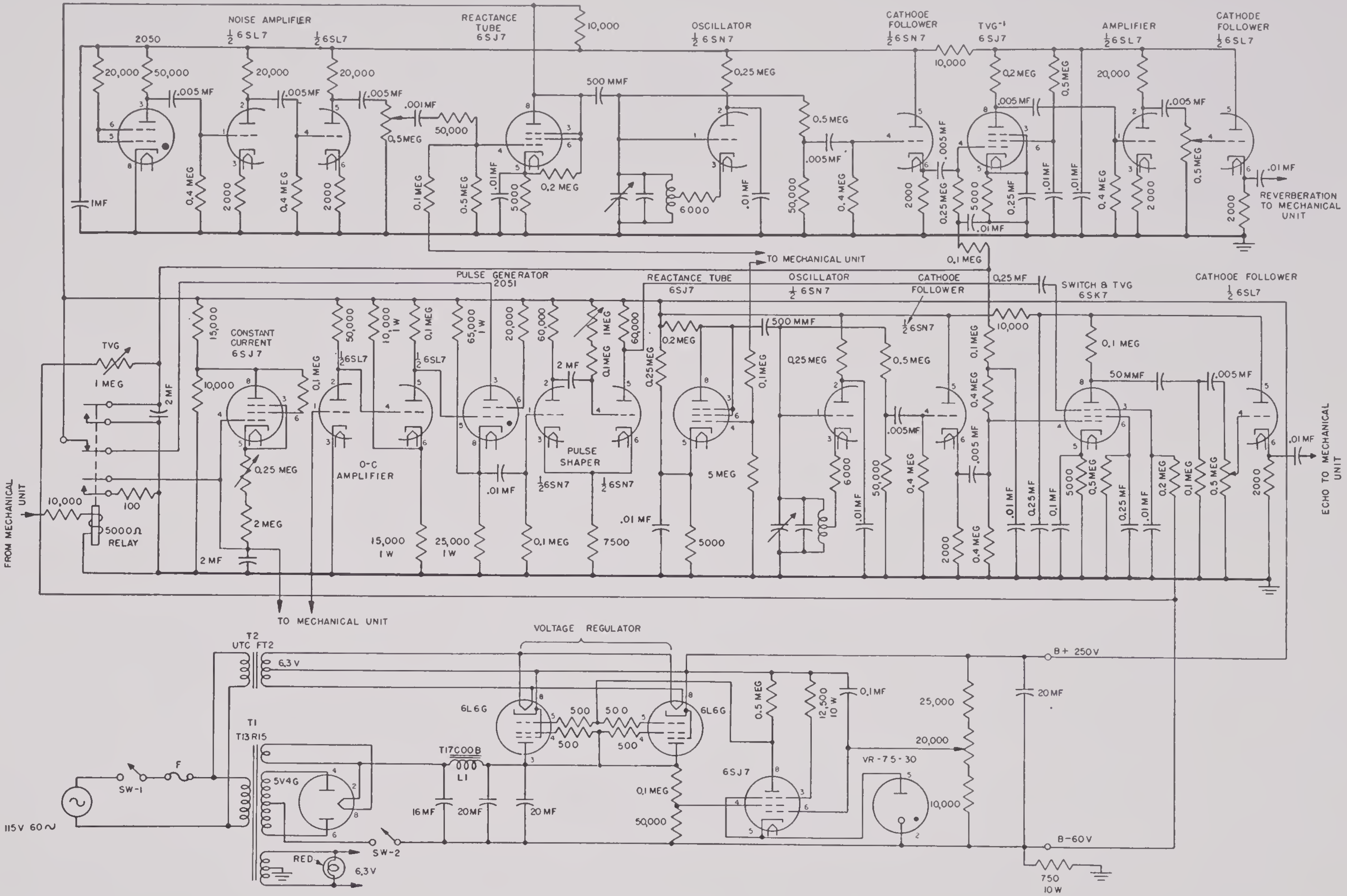
NOISE AMPLIFIER
2050
½ 6SL7
½ 6SL7
REACTANCE TUBE 6SJ7
OSCILLATOR ½ 6SN7
CATHODE FOLLOWER ½ 6SN7
TVG⁻¹ 6SJ7
AMPLIFIER ½ 6SL7
CATHODE FOLLOWER ½ 6SL7
REVERBERATION TO MECHANICAL UNIT
TO MECHANICAL UNIT
PULSE GENERATOR 2051
REACTANCE TUBE 6SJ7
OSCILLATOR ½ 6SN7
CATHODE FOLLOWER ½ 6SN7
SWITCH & TVG 6SK7
CATHODE FOLLOWER ½ 6SL7
ECHO TO MECHANICAL UNIT
TVG
1 MEG
CONSTANT CURRENT 6SJ7
0-C AMPLIFIER
PULSE SHAPER
FROM MECHANICAL UNIT
5000Ω RELAY
TO MECHANICAL UNIT
VOLTAGE REGULATOR
T2 UTC FT2
6.3 V
6L6G
6L6G
6SJ7
VR-75-30
B+ 250V
B-60V
750 10 W
T1 T13R15
5V4G
T17C00B L1
16MF
20MF
20 MF
SW-1
SW-2
F
115V 60~
RED
6.3V

FIGURE 7. Wiring schematic for OTE-2.

bearing. The projector bug is coupled to the training wheel on the sound stack through a servo-synchro system, while the pointer is controlled by a target-bearing cam on the program record being used. Thus, whenever the operator is following the target bearing closely, the position of the bug will coincide with that of the pointer. Observation of these two indicators enables the instructor to keep a continuous check on the performance of the operator in determining target bearing.

Below the bearing indicator are two small windows which permit the instructor to check the values of doppler and range as they are called by the student.

During the attack the sliding drawer shown protruding from the lower part of the panel in Figure 5 carries a sheet of standard letter paper on which a pencil lead traces a continuous record of all the bearings determined by the student operator. The pencil lead is connected mechanically to the bug of the bearing indicator and records the relative bearing of the projector by transverse motion. The drawer, which is closed at the beginning of the attack, is driven outward as the attack proceeds by a constant-speed motor controlled by the switch on the panel of the mechanical unit marked "program." Drive is effected through a rack that can be disengaged at the end of the attack. As the drawer moves out, the active edges of the cams on the program record move against their respective followers and so transmit to the electronic unit the three types of attack information referred to above. The time required for the drawer to open its full distance is four minutes, which is ample for most attacks.

At the end of the run the paper is removed from the drawer, and a line showing the correct sequence of bearings is superimposed on the student's trace simply by placing the program record on the paper and drawing a pencil along the bearing cam. A typical record is shown in Figure 8.

Echo timing, target doppler, and bearing in the mechanical unit are controlled by means of cam followers that move on the rectilinear cams on the program records, one of which is shown in Figure 5. A record is built up from three pieces of hard Masonite, each with one straight edge. In making the record, the pieces are stacked and glued together with the straight edges in line. The curved edge of the largest piece is cut as a rectilinear cam in accordance with the variation in relative target bearing during the attack which is being simulated. Similarly, the curved edges of the middle-sized and smallest pieces are cut to correspond to data pertaining, respectively, to target doppler and target range variation. A sketch of the entire attack is drawn on the back of the program record for the convenience of the instructor in selecting the type of attack he wishes to reproduce for the student operator.

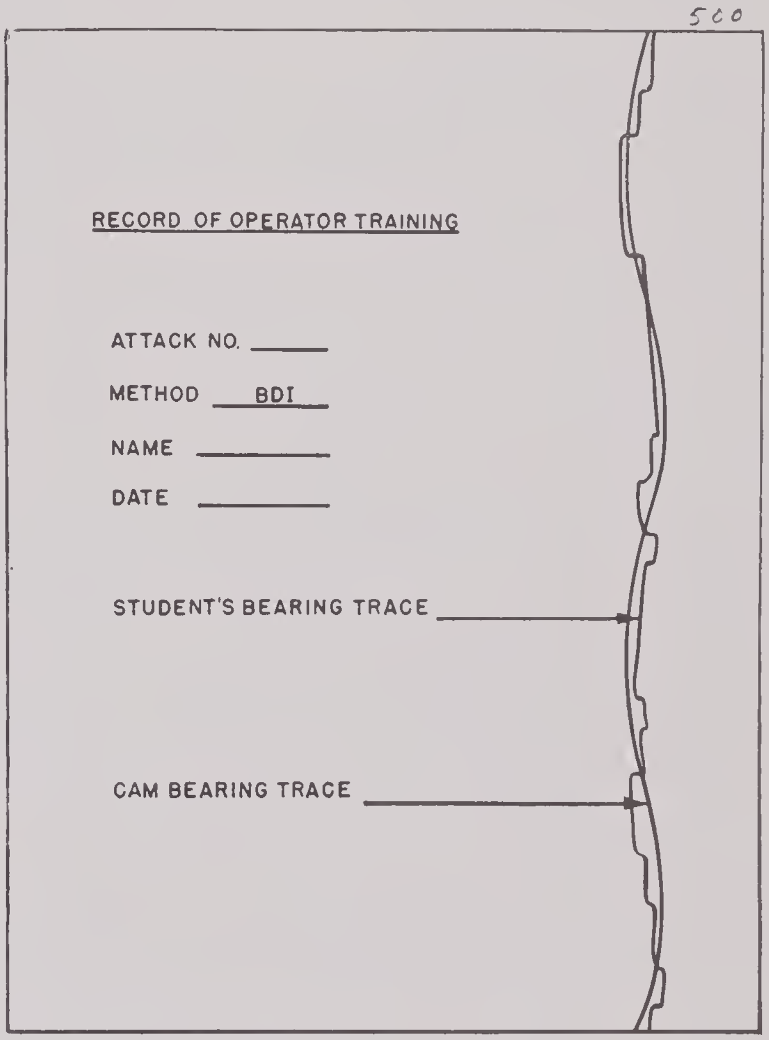

FIGURE 8. BDI bearing performance record.

When in use, the program record fits against a set of guides in the left side of the movable drawer in the mechanical unit and it holds the recording paper in position.

6.7 ELECTRONIC UNIT

Reverberation and echoes encountered under actual service conditions possess certain characteristics that the OTE-2 must duplicate if it is to be satisfactory. These effects may be summarized as follows.

1. Reverberation is loud immediately after the ping and diminishes with time.

2. Reverberation is composed of a band of frequencies instead of a single frequency and shows irregular fluctuations in amplitude and phase at the two sides of the projector.

3. Echo intensity is a function of target range, decreasing as range increases.

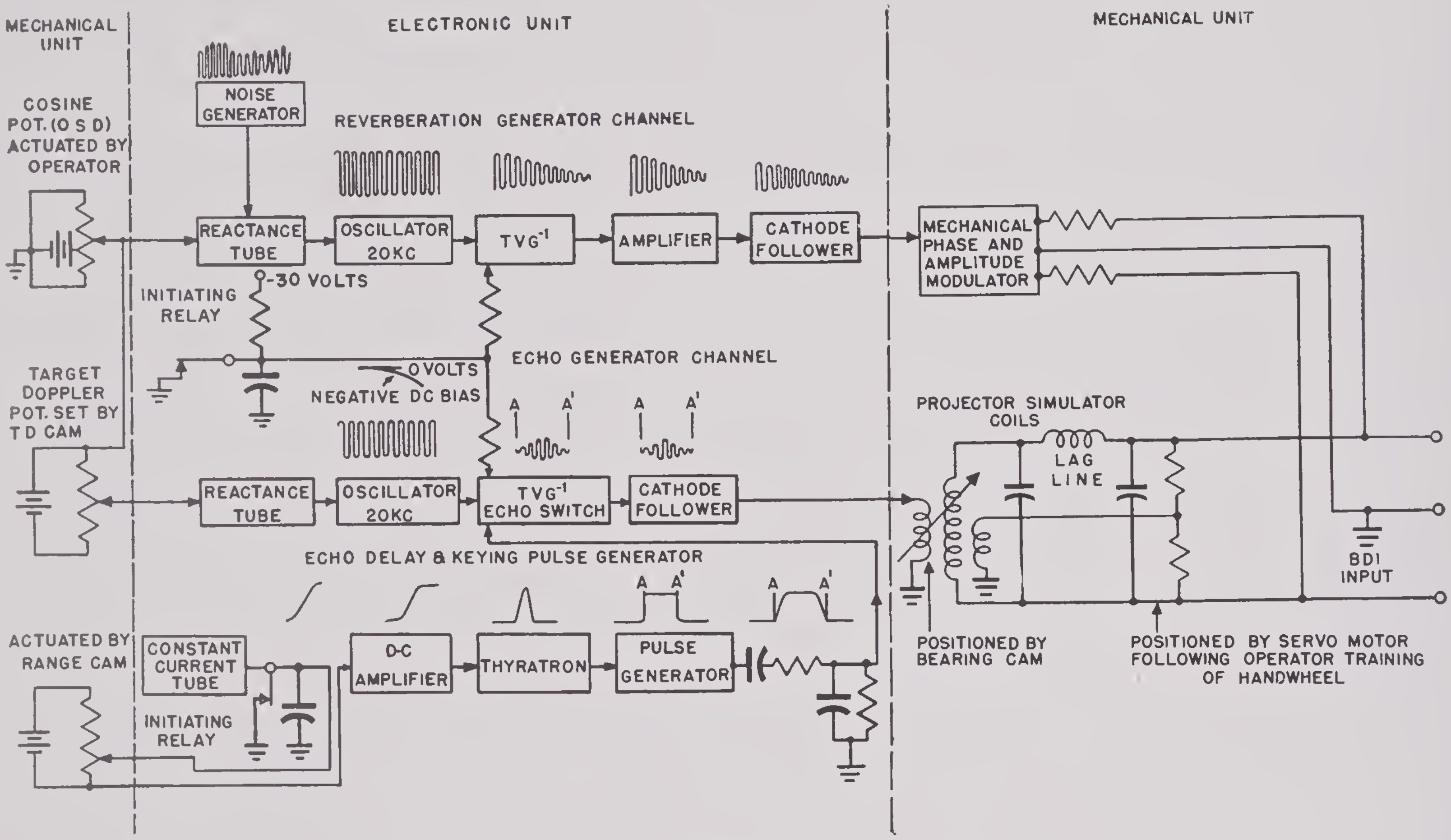
MECHANICAL UNIT
ELECTRONIC UNIT
MECHANICAL UNIT
NOISE GENERATOR
REVERBERATION GENERATOR CHANNEL
COSINE POT. (O S D) ACTUATED BY OPERATOR
REACTANCE TUBE
OSCILLATOR 20KC
TVG⁻¹
AMPLIFIER
CATHODE FOLLOWER
MECHANICAL PHASE AND AMPLITUDE MODULATOR
-30 VOLTS
INITIATING RELAY
0 VOLTS
NEGATIVE DC BIAS
ECHO GENERATOR CHANNEL
TARGET DOPPLER POT. SET BY T D CAM
A A' A A'
PROJECTOR SIMULATOR COILS
LAG LINE
REACTANCE TUBE
OSCILLATOR 20KC
TVG⁻¹ ECHO SWITCH
CATHODE FOLLOWER
BDI INPUT
ECHO DELAY & KEYING PULSE GENERATOR
POSITIONED BY BEARING CAM
POSITIONED BY SERVO MOTOR FOLLOWING OPERATOR TRAINING OF HANDWHEEL
ACTUATED BY RANGE CAM
CONSTANT CURRENT TUBE
INITIATING RELAY
D-C AMPLIFIER
THYRATRON
PULSE GENERATOR

Figure 9. Functional block diagram for OTE-2.

4. The echo, as received, is modified by a combination of two dopplers, one caused by own-ship's motion and the other by the motion of the target. The result of this combination may be to give an echo frequency either higher or lower than that of the ping, depending on the tactical situation.

The manner in which these effects are duplicated electronically in the OTE Model 2 is explained in the following paragraphs. In this connection the reader should refer frequently to the block diagram given in Figure 9, in which the type of signal emitted by each component is indicated.

Reverberation

The reverberation signal is generated by an oscillator operating at approximately 20 kc, the frequency of the sonar gear. This oscillator is frequency-modulated at random over a small band by a noise generator and a reactance tube. In addition, the frequency of the reverberation is adjusted by a d-c voltage applied to the reactance tube grid to include doppler from own-ship's motion. The value of this d-c voltage is determined by the projector bearing and the ship's speed as set into the device.

The output of the oscillator is passed through an inverse time-varied gain stage that causes the signal level to decrease with time after the keying pulse is initiated. This decrease in level simulates the dying out of reverberation that follows the ping in ordinary sonar operation.

The output of the inverse TVG stage is fed into a mechanical phase-and-amplitude modulator located in the mechanical unit. This modulator consists of a motor-driven rotary cam of irregular contour that activates two cam-follower arms bearing on it on opposite edges.

Each of these arms carries a small coil which, because of the irregular shape of the cam, is made to move back and forth across the face of two stationary coils that are connected in phase opposition. The output of one set of the stationary coils is phase-shifted through 90 degrees and the output of the other set is connected between the electric center of the lag-line load and ground. The net result is an output that consists of two channels, with reference to ground, that are of random relative phase and amplitude because of the motion of the moving coils. The signal finally obtained is intended to duplicate the characteristics of the reverberation obtained in actual echo ranging with a split projector.

When the unit is used with equipment that does not include BDI and a split projector, the two channels are connected together. In this case the output from the center of the bridging network will be equivalent to the output of an unsplit projector.

Time Delay and Echo-Triggering Pulse

The keying pulse is fed into a circuit that gives it a time delay corresponding to the range of the echo as established by the range cam on the program record. This circuit operates as follows.

A 6SJ7 tube is connected so as to operate as a constant-current pentode. The current from this tube charges a capacitor in series with a potentiometer that gives a voltage determined by the range cam on the program record. The time delay is a linear function of this voltage.

The sum of the capacitor voltage and the variable potentiometer voltage is applied to the input of a two-stage d-c amplifier. The output of the d-c amplifier raises the grid voltage of a thyratron. When the thyratron fires, it delivers a positive pulse across the load resistor between the cathode and ground.

This positive pulse excites a typical multivibrator-type pulse generator which then delivers another positive pulse, the length, shape, and amplitude of which are determined by fixed time constants in the multivibrator circuit. This second positive pulse is then applied to the grid of the echo-keying tube, making it conducting and permitting passage of a pulse of the oscillator signal that serves as the echo.

Generation

The oscillator that initiates the echo signal has an associated reactance tube that is activated by a d-c potential composed of two parts, one representing own-ship's doppler as determined by the training of the projector, and the other representing target doppler as determined by the doppler cam on the program record. When the target doppler is equal to zero, the echo-oscillator frequency is equal to the mean frequency of the reverberation oscillator.

The output of the echo oscillator is fed into an inverse time-varied gain switching stage, the grid bias of which is increased in a negative manner as a function of time so that its output level drops as a function of time after the keying pulse (ping) is sent out. This decrease in level is so adjusted that it simulates the normal decrease of echo level as a function of target range.

This stage is kept inoperative by a large negative bias on the suppressor grid, and thereby prevents the echo signal from passing to the other circuits until such time as is specified by the setting of the range cam on the program record. At this time the positive pulse from the multivibrator generator is applied to the suppressor grid, canceling the negative bias and permitting normal operation. The gain, and as a consequence the intensity, of the emitted echo, are determined by the amount of bias on the grid at the time the keying pulse occurs. The intensity of the simulated echo thus becomes a function of target range, just as it is in actual echo ranging.

The output of this switching stage is delivered to a cathode-follower stage that acts as an impedance-matching device to pass the signal to the projector simulator coils in the mechanical unit. These coils, when properly aligned by the operator, allow the signal to pass into the BDI and give right, left, or center indication, according to their relative placement.

A complete circuit diagram of OTE Model 2 is shown in Figure 7.

6.8 MECHANICAL UNIT

The mechanical unit contains all of the problem-generating elements, including the motor-driven program-record drawer previously described. The various components of this part of the equipment operate as follows.

THE TARGET BEARING, DOPPLER, AND RANGE CAMS

The target-bearing cam operates mechanically through a gear section and follower gear, to revolve the exciter coil of a set of projector simulator coils so that at any moment the position of this coil gives the called-for bearing angle of the target.

The target doppler cam varies the position of the arm on a potentiometer, which delivers a d-c voltage proportional to the called-for target doppler.

The target range cam, through a cam follower, adjusts a potentiometer similar to the one mentioned above, which delivers the d-c range-determining voltage mentioned in the discussion of time delay and echo-triggering pulse generation.

THE SIMULATOR COILS

The amplitude and quadrature coils of the set of projector simulator coils[a] are carried by a disk that is driven by a servo-synchro system. This servo drives the amplitude and quadrature coils so that they assume a position corresponding to the bearing which the operator has set on the sonar stack training wheel. When the operator trains close to the bearing called for by the cam, the projector simulator coils approach coincidence and, as a consequence, echoes are heard, and right, left, or center indications are obtained on the BDI. These indications correspond to the relative positions of the cam-driven exciter coils and the quadrature and amplitude coils manipulated by the operator.

The servo system that drives the quadrature and amplitude coils also moves the recording pencil in a corresponding linear motion perpendicular to the motion of the drawer. As stated before, this pencil records the performance of the operator in tracking the target.

The bar that carries the pencil also moves a contact across a potentiometer strip. This potentiometer is so shaped that it delivers a voltage the amplitude of which is proportional to the cosine of the angle of deviation of the operator-controlled relative projector bearing. The absolute value of this voltage is controlled by a potentiometer located on the panel of the unit and graduated in ship's speed. Thus, the voltage delivered is proportional to the doppler caused by own-ship's motion. This potentiometer must be set by the instructor to the speed of the attacking ship, which is indicated on the back of the program record.

KEYING CONTROL (PINGING)

In order that the keying may be done at the proper range rate, the keying signals may be taken from either the sonar stack or from a range recorder. However, keying for the standard range scales of 1,000 and 2,000 yd is available in the mechanical unit itself in case it is inconvenient to use either of the above sources. The type of keying to be used is controlled by a three-position switch located on the panel of the unit.

The keying built into the mechanical unit is accomplished by a cam driven by the same motor that operates the mechanical phase and amplitude modulator coils. The cam may be made to operate either or both of two contacts that are 180 degrees apart. Since the cam rotates once every 2½ sec, the use of one contact gives keying equivalent to a 2,000-yd range, and the use of both contacts gives keying equivalent to a 1,000-yd range.

6.9 GENERAL DESCRIPTION OF OTE-10

During the later stages of the development of OTE Model 2, it seemed that the device might lend itself to training several operators simultaneously, by the use of one master unit such as the OTE Model 2, to furnish attack information to several student positions at the same time. The proposed extension of the device was designated OTE Model 10.

At the instructor's station there was to be a mechanical unit similar to that described for OTE Model 2, and the attack problem was to be generated by the same type of program record and other equipment as before. No record of operator performance would be made, however, at this station. If it were decided that ship's course must be simulated so as to appear on the student-station gyro repeaters, a fourth cam could be added to each of the program records. The instructor's station would also include an electronic unit similar to the one used in OTE Model 2.

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[a] For a complete discussion of the operation of projector simulator coils, see Chapter 11 of this volume.

Each student station, located in a separate booth, would contain either a standard sonar equipment, with or without BDI, or a mockup stack. Mounted on top of each student's sound stack would be an arrangement similar to the one in the drawer of the OTE-2 mechanical unit for recording the student's performance in following the target bearing. Experience with the Model 2 unit has shown that it might be desirable to have this part of the equipment record the student's bearing error for each point on the bearing trace rather than his actual obtained bearing, since such a procedure would permit a more open bearing scale.

The placement of the simulator coils in the OTE-10 student recorder would differ somewhat from the OTE-2 arrangement in order to permit plotting bearing error on the student's record sheet. A servo-synchro system would provide a motion proportional to the target bearing called for by the problem. This system would be connected to one side of a mechanical differential, and the other side would be activated by the student's turning the bearing-training handle. The output of the differential would then be equal to the angular difference between the target bearing and the bearing obtained by the student. This mechanical motion, which would be relatively easy to accomplish, would change the position of only one exciter coil in the simulator coil assembly, while the other three projector coils would remain fixed.

6.10 CONCLUSIONS

Only one unit of OTE Model 2 was constructed. Laboratory tests indicated that its performance was functionally satisfactory but that the mechanical design was insufficiently rugged. The OTE Model 2 equipment provides a relatively simple method of simulating a number of the essential conditions that exist in an actual attack. With it, the student operator using actual sonar gear can gain experience and practice in attack procedure. While doing this, he makes a permanent record of his own performance that may be used for evaluation purposes and kept for future reference.

The OTE Model 10 design offers the possibility of giving a number of student operators simultaneously the kind of instruction and practice that OTE-2 provides for one student at a time. It has been estimated that runs could be made with this equipment at the rate of approximately six per hour, with ten to twelve student operators participating in each run. Thus, OTE Model 10 would accomplish a considerable economy of time in the use of skilled instructor personnel.

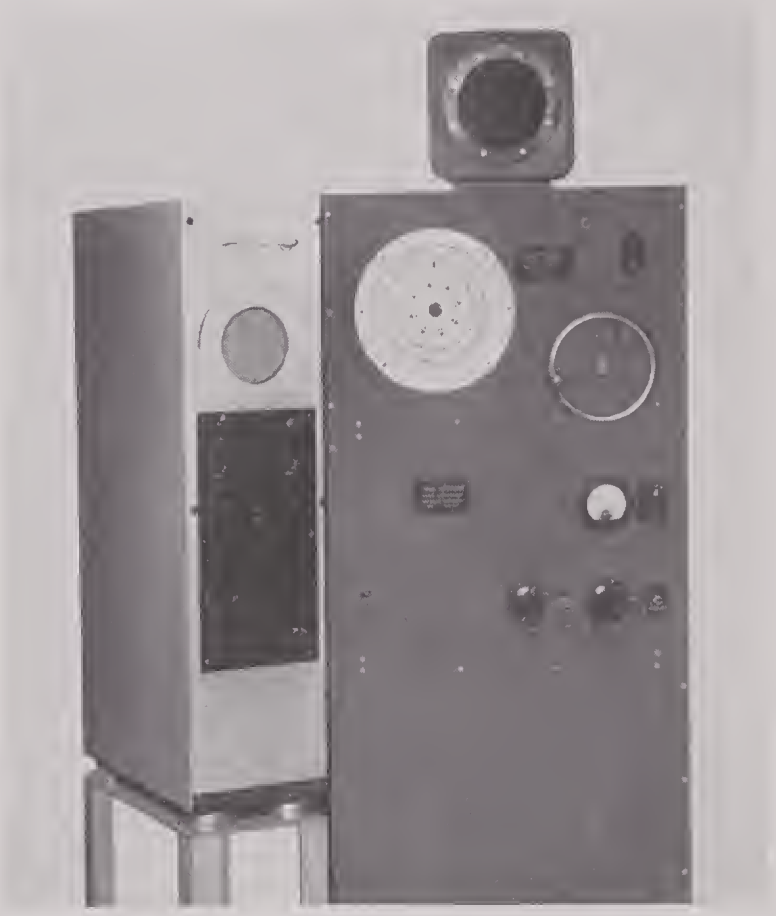


FIGURE 10. BDI trainer (left) with advanced bearing teacher.

BDI Trainer

The BDI trainer (Figure 10), developed by UCDWR, is a device for use in conjunction with the advanced bearing teacher or the Sangamo attack teacher to simulate BDI indications for training purposes. It was also intended to serve as a component of the group operator trainer [GOT]. It is similar in appearance to a BDI unit, with dummy balance and input selector controls. A range selector switch provides range settings at 1,000, 2,000, 3,000, and 5,000 yd. A gain attenuator controls the amplitude of reverberation and target echo deflections on the BDI oscilloscope screen. Reverberation and echo signals, along with keying pulses, and true bearing information for both target and projector are supplied by the associated attack teacher.

6.11 INTRODUCTION

Concurrently with the Harvard development of the OTE-8 as a BDI training aid for use with the QFD advanced bearing teacher, other engineers were working on a similar device, known as the BDI trainer, functioning on a different principle. While OTE-8 independently produces ultrasonic reverberation and echo signals in synchronism with those of the QFD, the BDI trainer is designed to utilize the signals generated by the advanced bearing teacher or the Sangamo attack teacher itself. It was also intended that the BDI trainer should become a component part of GOT. Since the development of GOT was delayed because of priorities, and the BDI trainer was meanwhile completed, the latter was delivered to the West Coast Sound School [WCSS] as a separate unit for service with existing training devices.

6.12 CHASSIS DESCRIPTION

The cabinet and controls of the BDI trainer are similar to those of the regular BDI (see Figures 10 and 11). As the attack teacher keys, the cathode-ray spot starts at the bottom of the screen and proceeds upward at a speed determined by the setting of the range selector switch (1,000, 2,000, 3,000 or 5,000 yd). The amplitude of the reverberation and echo deflections is controlled by the gain attenuator on the right. (The balance and input selector controls are dummies on this model but may be made to perform as on the BDI.) The associated attack teacher supplies echo, reverberation, keying pulse, true target bearing, and true projector bearing information necessary for the operation of the BDI trainer.

6.13 DESCRIPTION OF CIRCUITS

Right-Left Echo Channels

The echo signal after amplification is split into two channels for right and left echo deflection. The bearing control section operates the bias of these tubes so that transmission of the echo through each channel occurs at two or three degrees off the center bearing of the target. The echo voltages are rectified, combined, filtered, and then applied to the cathode-ray oscilloscope [CRO] amplifier so that one channel or the other supplies the echo pulse to the rectifiers as the projector bearing changes from right to left of the target bearing. A corresponding positive or negative pulse from the rectifier is supplied to the CRO amplifier to move the spot on the screen either to the right or the left corresponding to the target bearing deviation from the projector bearing, the range, and the amplitude of the received echo.

Bearing Control

To obtain the right-left indications, the voltages from the true projector bearing repeater are connected to a control transformer whose rotor is positioned by the true target bearing. The coupling and adjustment is such that zero voltage is developed across the resistors of the control transformer when the projector and target bearings are the same. When these bearings differ, a 60-c voltage will appear, the magnitude depending upon the difference between the target bearing and the projector bearing.

This voltage is impressed through isolating

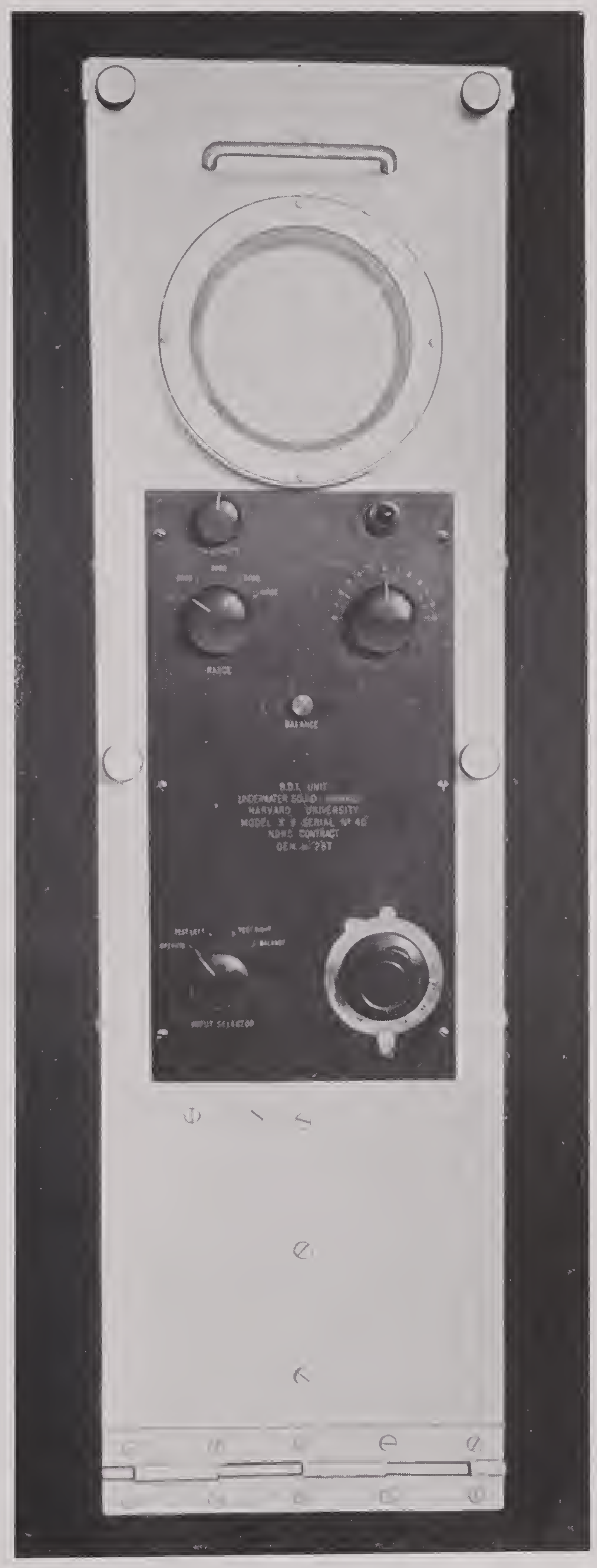


Figure 11. BDI—front panel.

resistors to the control grids of a twin triode V-110. The cathodes of V-110 are phase-displaced by a 60-c voltage. This results in a phase difference between the a-c voltage on the cathode and the a-c voltage on the grid at each half of the tube V-110. Therefore, as the projector is trained through the target bearing, the a-c voltage applied to the grids of V-110 undergoes a 180-degree phase reversal. One half of tube V-110 will draw its maximum current when the projector bearing is slightly to the right of the target bearing and the other half when the projector is trained slightly to the left of the target bearing.

The outputs of V-110 are filtered, and the d-c component is used to control the echo channels for right-left deflection. The bias adjustment potentiometers P-9 and P-10 are used to control the width of the lobes, which, in this case, are set at approximately a total width of 40 degrees. Therefore, the BDI trainer does not recognize width of targets but is dependent on the amplitude of the echo received from the attack teacher for cut-ons and cut-offs.

Reverberation

The reverberation is amplified in one half of the twin triode V-107 and is then applied to one half of the diode V-108 for rectification. The rectified reverberation pulses are applied to a 30-c band-pass filter. This band-pass filter blocks all but the 30-c component, which is then combined with the d-c pulses from the echo channel and applied to the CRO amplifier. Therefore, the visual reverberation is synchronized with the audible reverberation in length and decay time.

CRO Amplifiers—Sweep and Intensity Modulation

A pentode, V-101, is used as the sweep generator and is similar to the one used in the BDI. A bridge is formed by a positive and negative power supply, the vertical deflection coil, and tube V-101. The speed of the sweep is determined by the capacity of the condenser C-1. The intensity modulation is obtained by combining a portion of the echo and reverberation from the inputs, amplifying them in one half of triode tube V-109 and rectifying them

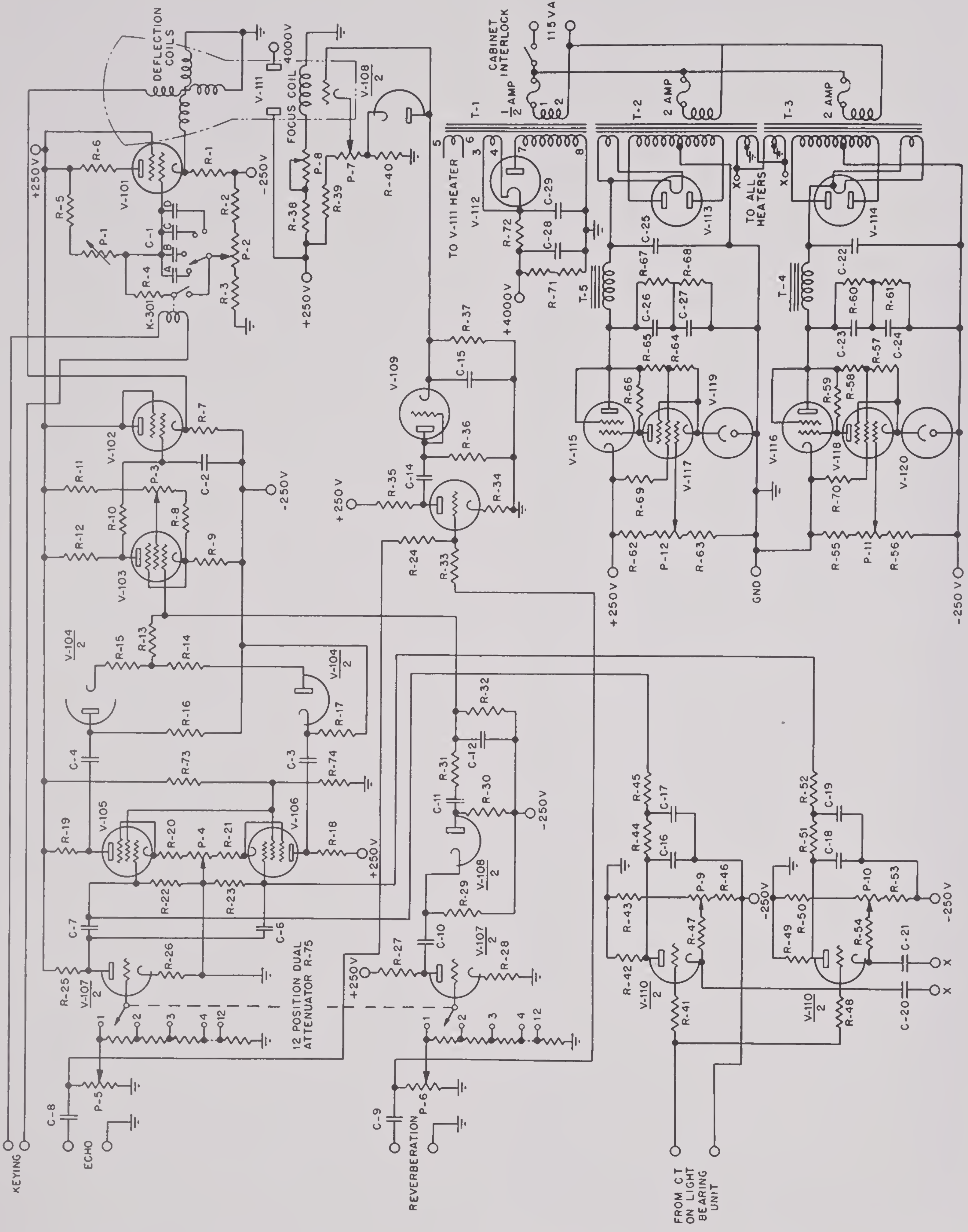

DEFLECTION COILS
4000V
V-111
FOCUS COIL
V-108/2
CABINET INTERLOCK
115 VAC
1/2 AMP
2 AMP
2 AMP
T-1
T-2
T-3
TO V-111 HEATER
V-112
V-113
V-114
TO ALL HEATERS
+250V
-250V
+4000V
V-101
V-102
V-103
V-104/2
V-105
V-106
V-107/2
V-109
V-110/2
V-115
V-116
V-117
V-118
V-119
V-120
K-301
T-4
T-5
GND
12 POSITION DUAL ATTENUATOR R-75
KEYING
ECHO
REVERBERATION
FROM CT ON LIGHT BEARING UNIT

FIGURE 12. Electrical schematic for BDI trainer.

in the other half connected as a diode. The output is then filtered and applied to the control grid of the CRO tube V-111, so that the presence of any reverberation or echo generates a positive voltage which decreases the bias and thus brightens the spot on the CRO tube V-111. One half of the tube V-108 is connected from the control grid of tube V-111 to its cathode divider P-7 and R-40 to serve as an intensity limiter so that the brightening can never exceed certain limits. Two regulated voltage supplies are furnished to minimize drifting of the CRO spot.

6.14 ADVANCED BEARING TEACHER CONNECTION

Some modifications are necessary in connecting the BDI trainer to the advanced bearing teacher.

1. The echo and reverberations must be brought out separately and supplied to the BDI trainer.

2. A keying adapter must be used to actuate the keying relay in the BDI trainer since no current may be drawn from the voltage pulse already contained in the bearing teacher.

3. A small i-f autosyn repeater must be geared to the target bearing in the mechanical portion and a 1-CT control transformer geared to the handwheel for projector bearing. The control transformer feeds into the BDI trainer. Either the i-f autosyn or the 1-CT control transformer must then be rotated until a voltage null is obtained when the handwheel is trained to center bearing.

6.15 SANGAMO ATTACK TEACHER QFA-2 CONNECTION

Modifications are also necessary in connecting the BDI trainer to the Sangamo attack teacher (QFA-2).

1. A separate light source must be added to the QFA-2 to generate true target bearing. This light source projects a series of parallel lines on to the screen surrounding the projected images of the vessels. These lines must be kept parallel with an imaginary line between the two vessels by manual operation. This is accomplished by turning the knob on the light projector which rotates the lenses of the projector. The lens rotating mechanism is geared to the rotor of the 1-CT control transformer.

2. A keying adapter must also be used on the QFA-2 since only a voltage pulse is available on this model.

3. In order to obtain echo and reverberation signals on the BDI trainer, separate lead connections must be made to the electronic chassis in the QFA-2.

6.16 SUGGESTED IMPROVEMENTS

1. A keying circuit operating from a voltage pulse should be incorporated, since most of the equipment with which it may be operated will have only voltage pulses available.

2. A better light source is indicated for use with the Sangamo attack teachers since the BDI trainer can indicate training errors of 1 degree or less. The light source now in use shoots parallel lines onto the screen, surrounding the submarine and attacking vessel. These lines are neither close enough together nor anchored to either ship for easy alignment to within 1 degree of the true target bearing. Therefore, either additional lines are needed or a single beam anchored at one ship in the manner of the Sangamo BDI trainer.

3. With the first attempt at connecting the BDI trainer to the QFA-2 attack teacher, a very poor signal-to-noise ratio was encountered. No attempt was made to correct this defect.

4. As there is more than sufficient gain in the echo and reverberation channels in this model, the BDI trainer may be simplified by omission of one or two tubes.

The group operator trainer was developed to overcome the disadvantage of individual instruction to each student and to bring instruction up to date through the use of more recent types of sonar stacks. Moreover, the trainer adds a number of new and more realistic sound effects and facilitates the teaching of various stack adjustments that were not possible on the advanced bearing teacher.

The GOT equipment (see Figure 13) comprises ten soundproof booths containing standard QGB or QJB stacks, and a master station for the instructor. The operator stacks include simulated transducers and have certain circuits revised to fit the application. The master station includes a sound effects chassis, a follower chassis, a keying chassis, a program generator, and ten indicators. These components and their operation will be described in the following section.

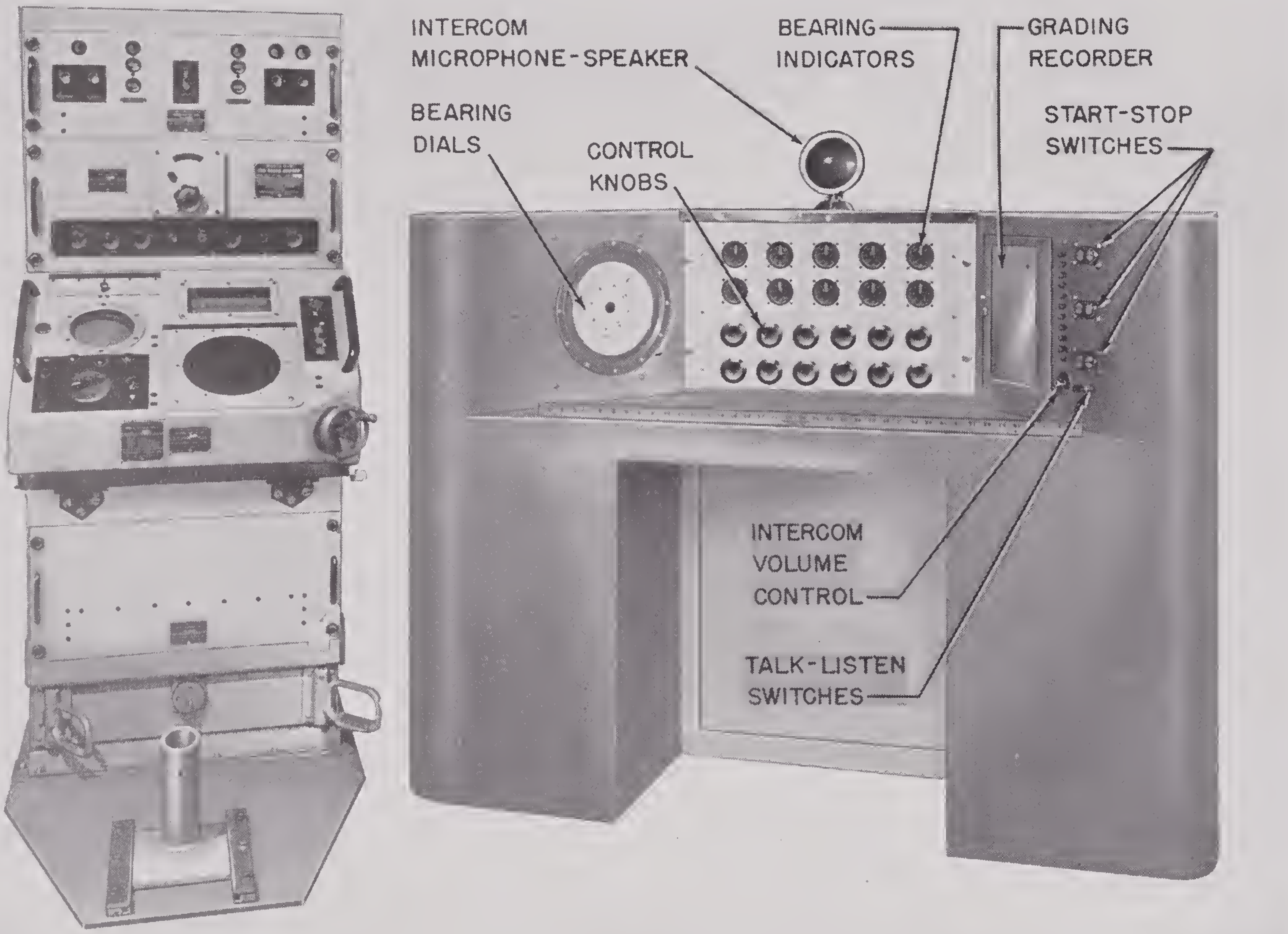

INTERCOM MICROPHONE-SPEAKER
BEARING INDICATORS
GRADING RECORDER
BEARING DIALS
CONTROL KNOBS
START-STOP SWITCHES
INTERCOM VOLUME CONTROL
TALK-LISTEN SWITCHES

FIGURE 13. Standard QGB stack and master station console.

Group Operator Trainer

The group operator trainer [GOT], developed by UCDWR, is a device which simultaneously trains ten student ASW sonar operators (five on QGB and five on QJB equipment) under the direction of one instructor. It presents to the operators six different cam-controlled attack problems or continuous series of automatically generated ranges and bearings, together with realistic sound effects. Ten indicators on the master station show the instructor the correct center bearing of the submarine and the bearing to which each student is trained. Another indicator permits a permanent record of each student's performance in training on the target. An intercommunications system allows the instructor to listen to each student's reports at will and to give individual or group instruction.

6.17 GENERAL DESCRIPTION

The master station console, shown in Figure 13, has three panels. On the left-hand panel are concentric bearing dials, on which a bug indicates the "right answer" center bearing of the submarine. On the center panel, ten dials indicate the respective bearings to which the students' "projectors" are trained. Below these are control knobs, which regulate the various sound effects, the depth of the "submarine," and other factors of the problem. On the right-hand panel are grading-recorder control buttons for the two-way communication system between instructor and students, and three on-off switches. The latter are to switch the power, to start the problem, and to reset the problem, respectively.

Once a problem is started, the simulated relative movements develop independently of the instructor and the students. The cam arrangement that controls the problem is so constructed that own ship is conned perfectly for the attack. Six different attacks are included in the repertoire of the device. These are grouped in three pairs, each consisting of an attack and a reattack. The instructor can select any one of the pairs by an adjustment made through a side opening in the console.

A student QGB station is shown in the left-hand side of Figure 13. Specific changes made in the QGB stacks include the substitution of a d-c selsyn transmitter for each bearing repeater selsyn. This is geared to the handwheel by a simple gear assembly. An electronically simulated projector is introduced into the stack to permit the echo to be heard on the proper bearings only. An electronic differential relay is also introduced to deliver information to the grading recorder. Circuits are arranged so that the bearing deviation indicator and the keying action of the indicator-recorder at each stack are controlled from the master station. A relatively simple wiring harness takes care of most of the wiring changes.

In each QJB stack, the driver amplifier assembly is removed and a QJB adapter and simulated transducer assembly is substituted. The power input transformer is rewired for 115 volts instead of for the customary 440 volts. The indicator-recorder and keying amplifier chassis wiring is revised to change the sequence of automatic keying and training to bring this sequence into conformity with the keying controls from the master station.

The master station measures approximately 32x45x60 in. and weighs 500 lb.

The names and the functions of the center panel controls are as follows.

1. The *reverberation gain* control varies simultaneously the intensity of reverberation, the water noise, and the surface wake effects.

2. The *reverberation range* switch selects the duration of reverberation sounds after each ping.

3. The *water-noise gain* varies the intensity of water noise.

4. *Water-FXR* switch. When this switch is set at FXR, sound conditions are simulated that are present when FXR gear is towed by own ship. The intensity of this noise is controlled by the water-noise gain control. When the switch is set at *water,* conditions without FXR are simulated.

5. The *propeller gain* control varies the intensity of own-ship's propeller sounds.

6. The *surface wake width, surface wake gain,* and *surface wake range* controls pertain to a simulated surface wake which has no relationship to the submarine. They control respectively the apparent width, echo intensity, and range of the surface wake.

7. The *flyback* switch sets the flyback at the indicated number of yards *beyond the echo range.*

8. The *echo-wake* control varies simultaneously the intensity of the submarine echo and submarine-wake echo.

9. The *depth* control varies range at which contact is lost on approach and therefore the apparent depth of the submarine.

10. The *tuning* control detunes all the stacks simultaneously to give the students experience in retuning their gear.

11. *Key* button. A momentary pressing of this button starts the keying cycle of the master station. Holding the button in for a long dash stops the keying cycle.

6.18 TECHNICAL DESCRIPTION

The technical description of the group operator trainer will center around the diagrams in Figures 14 and 15.

The sound-effects chassis generates water noise, FXR noise, reverberation tone, echo tone, and propeller modulation. These sounds are regulated by various center-panel controls, but whenever the time element must be controlled (as in ping duration and range-governed echo delay) the sound effects are triggered by pulses from the keying chassis. The output of the sound-effects chassis is fed through the follower chassis into the simulated transducers.

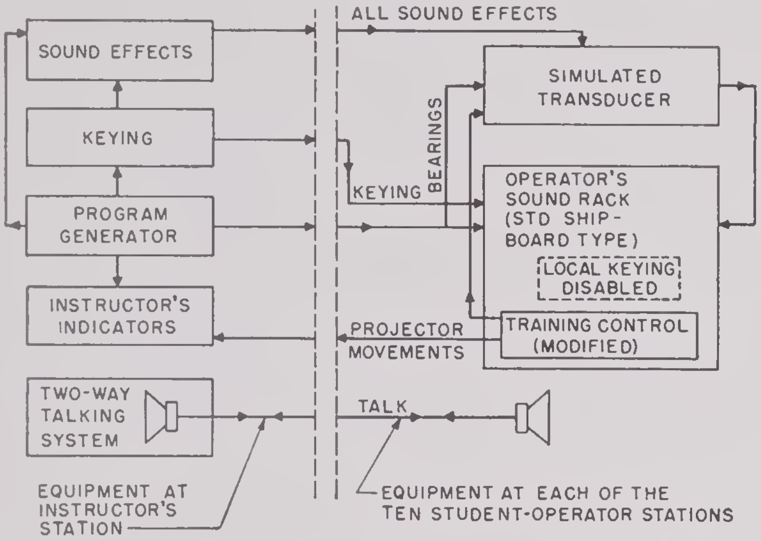


FIGURE 14. Simplified block diagram of group operator trainer.

The keying chassis contains a closed functional loop of timing circuits in which each successive timing operation is initiated by the preceding circuit; once started, the keying cycle is self-sustaining. Some of the time intervals change with the progress of the problem, and the control elements that govern them are located in the program generator. Besides regulating the production of sound effects, the output of the keying chassis provides keying and flyback pulses to all the student stations.

The mechanical-electrical program generator functions as the "brain" of the GOT and establishes the values of the eight variables that enter the problems of the trainer. Three of them (sub wake range, sub aspect, sub range) affect time intervals in the problems and are fed into the keying chassis; one (doppler) is fed directly into the sound-effects chassis; one (own course) runs the compass cards on all the student stations and on the left-hand panel of the master station; and three bearing variables (wake displacement, relative bearing of sub, target width) are fed into the simulated transducers.

The simulated transducer located at each student station compares the bearing set up by the problem generator with the bearing to which the student has trained, and if the student is on the target, the simulated transducer allows the submarine and wake echoes from the sound-effects chassis to enter the student's receiving circuits. The simulated transducer circuits allow the standard BDI on the stack to function normally.

Either turning the student's training handwheel or operating the automatic search performs five different functions: (1) the bug on the student's bearing dials is rotated; (2) the simulated transducer is rotated; (3) one of the ten projector bearing indicators at the master station follows and indicates the new bearing; (4) the grading recorder at the master station records any significant difference between the new and old projector bearings relative to the target bearing; and (5) the intensity of propeller and FXR noises is varied to correspond to the turning of the transducer toward or away from own-ship's screws.

SOUND-EFFECTS CHASSIS

The water and FXR noises are generated in the Type 2050 gas tubes V-1 and V-15, respectively. Use is made of the fact that the random irregularities in gas tube conduction produce a sound very much like water noise (Figure 15).

The output of the water-noise generator is used in three ways. (1) After passing through S-1 (water-FXR switch) and being amplified by V-8A, the noise voltage is applied to P-8 (water-noise gain), amplified by V-8B, and fed into Var-1 for frequency conversion and for mixing with other sounds. (2) The output of V-8A is also applied to P-6A (propeller gain), is modulated in the modulator V-9 by the output of the multivibrator V-10, and leaves the chassis through T-5 as own-ship's propeller noise. (3) The output of V-1 is coupled directly to the grid of V-2 to excite the reverberation tanks in the plate circuit of the latter tube.

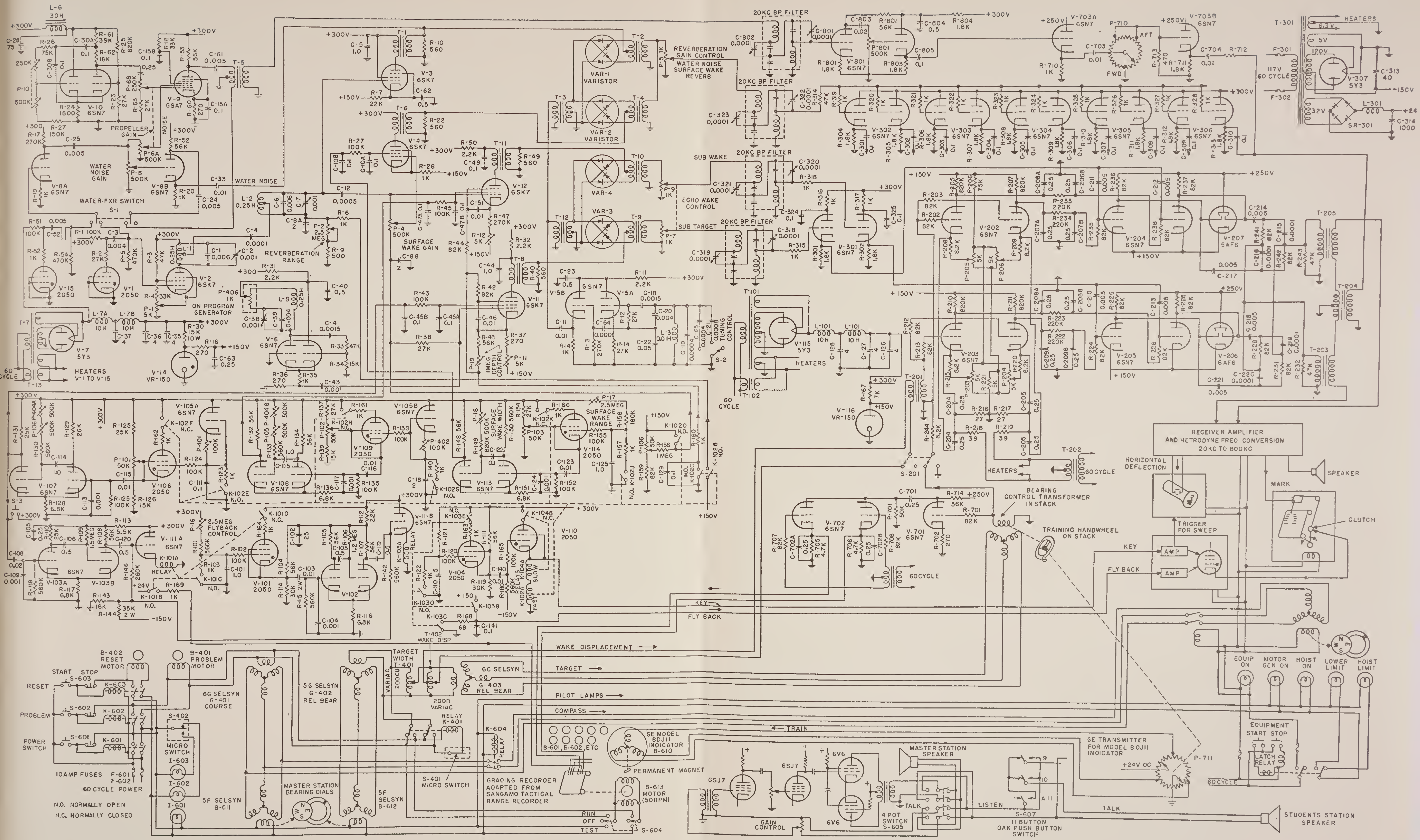

20KC BP FILTER
REVERBERATION GAIN CONTROL
WATER NOISE SURFACE WAKE REVERB
VAR-1 VARISTOR
VAR-2 VARISTOR
VAR-3
VAR-4
SUB WAKE
ECHO WAKE CONTROL
SUB TARGET
HEATERS
6.3V
5V
117V 60 CYCLE
V-307 5Y3
SR-301
WATER NOISE GAIN
PROPELLER GAIN
NOISE
WATER-FXR SWITCH
WATER NOISE
REVERBERATION RANGE
SURFACE WAKE GAIN
ON PROGRAM GENERATOR
HEATERS V-1 TO V-15
60 CYCLE
TUNING CONTROL
DEPTH CONTROL
SURFACE WAKE RANGE
SURFACE WAKE WIDTH
FLYBACK CONTROL
RELAY
FAST
SLOW
FWD
AFT
RECEIVER AMPLIFIER AND HETRODYNE FREQ CONVERSION 20KC TO 800KC
HORIZONTAL DEFLECTION
SPEAKER
MARK
CLUTCH
TRIGGER FOR SWEEP
KEY
FLY BACK
AMP
BEARING CONTROL TRANSFORMER IN STACK
TRAINING HANDWHEEL ON STACK
WAKE DISPLACEMENT
TARGET
PILOT LAMPS
COMPASS
TRAIN
B-402 RESET MOTOR
B-401 PROBLEM MOTOR
START STOP
RESET
PROBLEM
POWER SWITCH
10AMP FUSES F-601 F-602
60 CYCLE POWER
N.O. NORMALLY OPEN
N.C. NORMALLY CLOSED
MICRO SWITCH
6G SELSYN G-401 COURSE
5G SELSYN G-402 REL BEAR
TARGET WIDTH T-401
T-402 WAKE DISP
VARIAC
200B VARIAC
6C SELSYN G-403 REL BEAR
RELAY K-401
S-401 MICRO SWITCH
5F SELSYN B-611
MASTER STATION BEARING DIALS
5F SELSYN B-612
GRADING RECORDER ADAPTED FROM SANGAMO TACTICAL RANGE RECORDER
B-601, B-602, ETC
GE MODEL 8DJ11 INDICATOR B-610
PERMANENT MAGNET
B-613 MOTOR (5ORPM)
RUN OFF TEST
S-604
GAIN CONTROL
MASTER STATION SPEAKER
TALK
4 POT SWITCH S-605
LISTEN
S-607 11 BUTTON OAK PUSH BUTTON SWITCH
STUDENTS STATION SPEAKER
GE TRANSMITTER FOR MODEL 8DJ11 INDICATOR
+24V DC
P-711
60 CYCLE
EQUIPMENT START STOP
LATCH RELAY
EQUIP ON
MOTOR GEN ON
HOIST ON
LOWER LIMIT
HOIST LIMIT

FIGURE 15. Electrical schematic of group operator.

When S-1 is set at the FXR position, functions (1) and (2) of the preceding paragraph are accomplished by using the FXR noise source (V-15) instead of the water-noise source (V-1). In addition, part of the output of V-8B (now FXR noise) is fed directly into T-5 to be combined with the propeller sounds coming from V-9. When, later in the circuit, the intensity of the propeller beats is made dependent upon the relative bearing of the student's projector, part of the FXR noise will accordingly also be bearing-dependent.

The reverberation tanks in the plate circuit of V-2 consist of L-1, C-1, C-2, and L-2, C-6, C-7, respectively. They are loosely coupled to each other by C-4. Both tanks are tuned to 4 kc and are excited by the amplified output of the water-noise generator V-1. The wide-band character of the exciting source and the exchange of energy back and forth through C-4 combine to produce the wavering character of reverberations in the sea. The output of the reverberation tanks is used for three purposes: (1) ping reverberations are simulated by the portion of the output fed to the reverberation modulator, V-3; (2) tone for the surface wake echo is provided to the surface wake modulator, V-4; (3) tone for the submarine wake echo is provided to the submarine wake modulator, V-12.

The submarine echo is generated by the 4-kc echo oscillator V-6. This tube is actually a double triode, one half of which functions as a tuned-plate oscillator, feeding its output through the other half, which functions as a cathode follower. A potentiometer, P-406, slightly changes the resonant frequency to simulate the doppler effect. The output of V-6 is fed into the submarine modulator V-11.

The general functions of the four modulator stages, V-3, V-4, V-12, and V-11, are very much alike. These tubes are remote-cutoff type 6SK7 pentodes in which the variable gain characteristic is utilized. The gain is controlled by varying voltage from the keying chassis. The input to each tube is from one of the sound generators, and the output goes into a varistor frequency converter.

The reverberation modulator V-3 receives its tone excitation from the high side of the second reverberation tank discussed above. Under normal conditions, when the control grid is at a d-c ground potential through L-2, P-2, and R-9, the tube is biased beyond cutoff and no reverberation tones is fed to later stages. Upon the closing of contact K-102B in the keying chassis, condenser C-8A is charged to a positive 150 volts, reducing the grid bias on V-3, and causing the tube to supply a reverberation tone to the varistor frequency converter Var-1. After momentarily closing, contact K-102B reopens, and C-8A discharges through the series combination of P-2 (reverberation range) and R-9. The resultant increasing bias causes the output of V-3 to decrease until the plate current is again cut off.

The surface wake modulator V-4 receives its tone excitation from the high side of the second reverberation tank through P-4 (surface wake gain). Normally, the cathode is held at a positive d-c potential with respect to the control grid. The screen grid is at the potential of the left-hand plate of V-113 in the keying chassis, which is normally less than the V-4 cathode potential. The plate current is cut off, therefore, and there is no output from the modulator. V-4 gives an output only when the plate current of the left-hand half of V-113 is temporarily blocked, allowing the screen grid of V-4 to rise. In this modulator and in V-12 and V-11, the positive pulse from the keying chassis is fed to the screen grid through a filter network. The magnitude of the V-4 output is dependent upon the instantaneous grid bias, which in turn is dependent upon the time interval between the closing of K-102D and the above-mentioned blocking action. Contact K-102D closes momentarily at the time of the ping and charges C-8B to a positive 150 volts, which provides V-4 with a minimum bias and hence a maximum gain immediately after the ping. Then C-8B begins to discharge through P-106 and R-159, the bias increases, and the gain of V-4 decreases to simulate increasing range. The output of the modulator is fed into the varistor frequency converter, Var-2.

The submarine wake modulator V-12 receives its tone excitation from the high side of the second reverberation tank through C-12. The principles of operation for V-12 are very similar to those for V-4, as described above. V-12 is also keyed through its screen grid as V-4 is, except that the controlling tube in the keying chassis is V-108 instead of V-113. However, V-12 differs from V-4 in that the suppressor grid of the former performs a special blocking function. Normally, the suppressor grid of V-12 is at approximate cathode potential. At the instant of pinging, K-102C closes, and C-51 charges through R-44, so as to put the suppressor grid at a negative ground potential with respect to cathode. This potential blocks the plate current in V-12 until C-51 has partially discharged through R-44, P-19, and R-48. The time for this discharge to take place corresponds to the range within which the ASW vessel cannot receive echoes because of the depth of the submarine. Inasmuch as the lost contact range and the depth of the submarine have been assumed in the GOT to be proportional, the center panel control of the discharge-circuit element, P-19, has been labeled "depth control." The output of the modulator is fed into the varistor frequency converter Var-4.

The submarine modulator V-11 functions in exactly the same manner as V-12. The output of V-11 is fed into the varistor frequency converter, Var-3. Frequency conversion is accomplished in the sound-effects chassis by the combination of the modified Colpitts oscillator V-5 and each of the varistors, Var-1, Var-2, Var-3, and Var-4, coupled by appropriate transformers.

Each varistor receives the oscillator frequency and one of the 4-kc sound effects. The interaction between them produces a number of output modulation frequencies, among which is the difference frequency of about 20 kc that is later selected by filter circuits to the exclusion of all others.

The outputs of Var-1 and Var-2 are combined and fed through P-5 (reverberation gain control) into the follower chassis. The outputs of Var-3 and Var-4 are fed through P-7 and P-9, respectively, into the follower chassis. P-7 and P-9 are ganged on one control labeled "echo-wake."

FOLLOWER CHASSIS

The follower chassis (Figure 15) performs two functions: it selects from each of the four sound-effects channels a band of frequencies centered on 20 kc, and it then distributes the sound effects to the ten student stations.

Four identical band-pass filters are used, each consisting of two series-resonant circuits. Cathode followers are used to allow the use of low impedance lines in the distribution system and to decouple the student stations from each other.

KEYING CHASSIS

Detailed operation of the keying chassis is given in Figure 16. The left-hand and middle columns of Figure 16 cover the internal workings of the chassis, and the right-hand column describes the outgoing pulses that are fed to other sections of the GOT. The five trigger circuits (V-102, V-103, V-107, V-108, and V-113) used in the keying chassis are quite conventional.

PROGRAM GENERATOR

The program generator (Figures 15 and 17) is built around 24 cams that contain in their contours all the problem elements of the GOT. The cams are mounted on a shaft in eight groups of three each. On a second shaft parallel to the first one are pivoted eight cam followers, spaced so that there is one follower for each group of three cams. The followers ride corresponding cams in the eight groups; and the remaining 16 cams, which contain the details of the other two pairs of problems, are idle until selected for a new problem.

The camshaft is rotated through a drive-gear assembly which is driven by the problem motor, which advances the problem at a normal rate, or the reset motor, which reverses the problem at a rapid rate.

A switching cam, in addition to the 24 problem cams, forms a part of the drive-gear assembly. The cam operates two microswitches, which are displaced from each other by 90 degrees: (1) S-402, which alternately turns on the blue and green lights on the left-hand panel at the beginnings of the two problems; (2) S-401, which, in the middle of each problem, simultaneously reverses polarity on the relative-bearing selsyns G-402, G-403, and on the

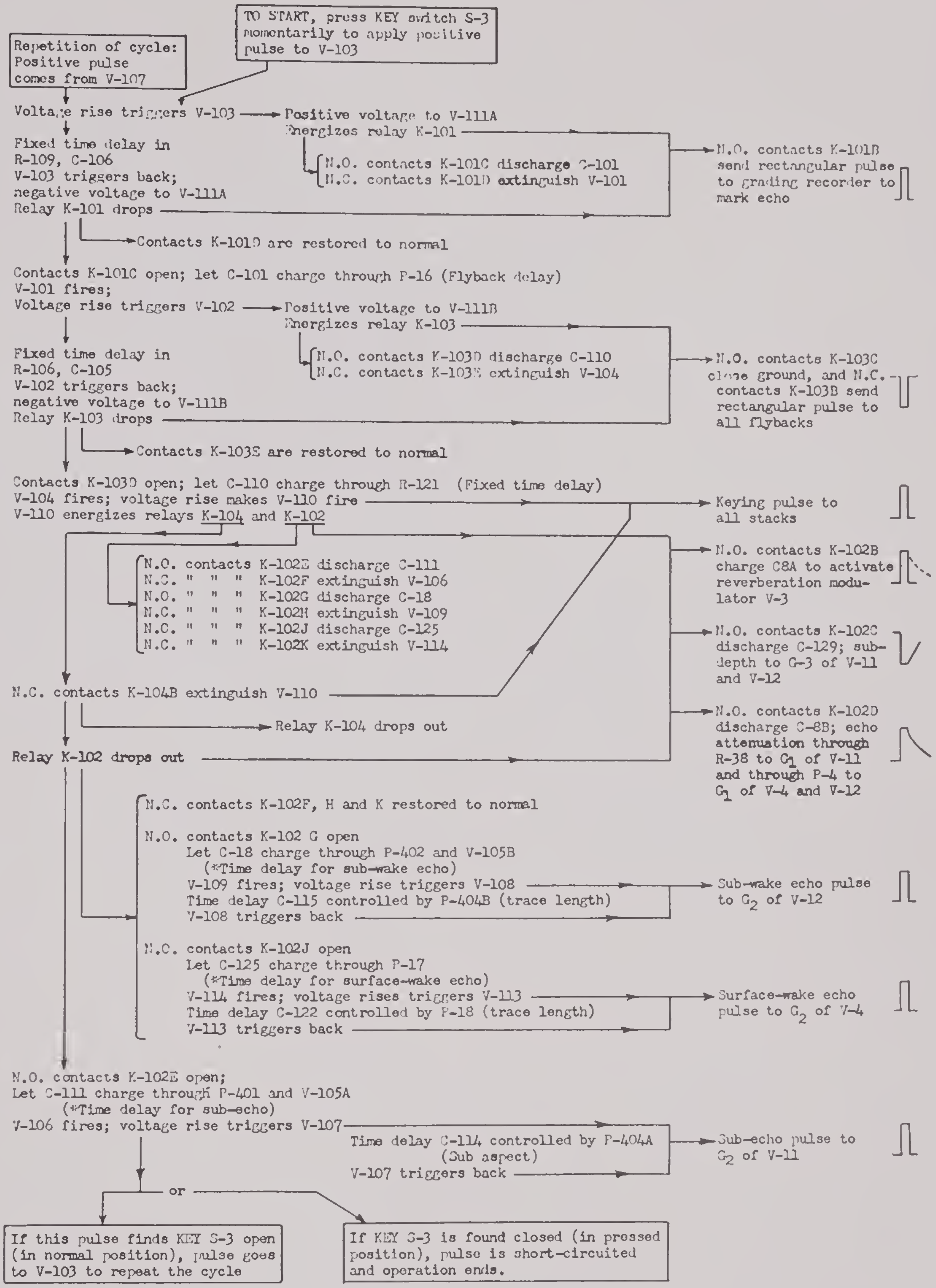

TO START, press KEY switch S-3 momentarily to apply positive pulse to V-103
Repetition of cycle: Positive pulse comes from V-107
Voltage rise triggers V-103
Positive voltage to V-111A
Energizes relay K-101
Fixed time delay in R-109, C-106
V-103 triggers back; negative voltage to V-111A
Relay K-101 drops
N.O. contacts K-101C discharge C-101
N.C. contacts K-101D extinguish V-101
N.O. contacts K-101B send rectangular pulse to grading recorder to mark echo
Contacts K-101D are restored to normal
Contacts K-101C open; let C-101 charge through P-16 (Flyback delay)
V-101 fires;
Voltage rise triggers V-102
Positive voltage to V-111B
Energizes relay K-103
Fixed time delay in R-106, C-105
V-102 triggers back; negative voltage to V-111B
Relay K-103 drops
N.O. contacts K-103D discharge C-110
N.C. contacts K-103E extinguish V-104
N.O. contacts K-103C close ground, and N.C. contacts K-103B send rectangular pulse to all flybacks
Contacts K-103E are restored to normal
Contacts K-103D open; let C-110 charge through R-121 (Fixed time delay)
V-104 fires; voltage rise makes V-110 fire
V-110 energizes relays K-104 and K-102
Keying pulse to all stacks
N.O. contacts K-102E discharge C-111
N.C. " " " K-102F extinguish V-106
N.O. " " " K-102G discharge C-18
N.C. " " " K-102H extinguish V-109
N.O. " " " K-102J discharge C-125
N.C. " " " K-102K extinguish V-114
N.O. contacts K-102B charge C8A to activate reverberation modulator V-3
N.O. contacts K-102C discharge C-129; sub-depth to G-3 of V-11 and V-12
N.C. contacts K-104B extinguish V-110
Relay K-104 drops out
Relay K-102 drops out
N.O. contacts K-102D discharge C-8B; echo attenuation through R-38 to G1 of V-11 and through P-4 to G1 of V-4 and V-12
N.C. contacts K-102F, H and K restored to normal
N.O. contacts K-102 G open
Let C-18 charge through P-402 and V-105B
(*Time delay for sub-wake echo)
V-109 fires; voltage rise triggers V-108
Time delay C-115 controlled by P-404B (trace length)
V-108 triggers back
Sub-wake echo pulse to G2 of V-12
N.C. contacts K-102J open
Let C-125 charge through P-17
(*Time delay for surface-wake echo)
V-114 fires; voltage rises triggers V-113
Time delay C-122 controlled by P-18 (trace length)
V-113 triggers back
Surface-wake echo pulse to G2 of V-4
N.O. contacts K-102E open;
Let C-111 charge through P-401 and V-105A
(*Time delay for sub-echo)
V-106 fires; voltage rise triggers V-107
Time delay C-114 controlled by P-404A (Sub aspect)
V-107 triggers back
Sub-echo pulse to G2 of V-11
or
If this pulse finds KEY S-3 open (in normal position), pulse goes to V-103 to repeat the cycle
If KEY S-3 is found closed (in pressed position), pulse is short-circuited and operation ends.

FIGURE 16. Keying sequence.

wake displacement Variac T-402, thus causing a 180-degree shift in bearing and a reversal of wake position to correspond to the passing of the ASW vessel over the submarine.

Figure 18 is a simplified sketch of a cam and its follower mechanism. The control element may be a variable resistor, a selsyn, or a Variac.

The first cam follower turns selsyn G-401, which in turn drives the master station compass-card selsyn (B-611) and the compass-card

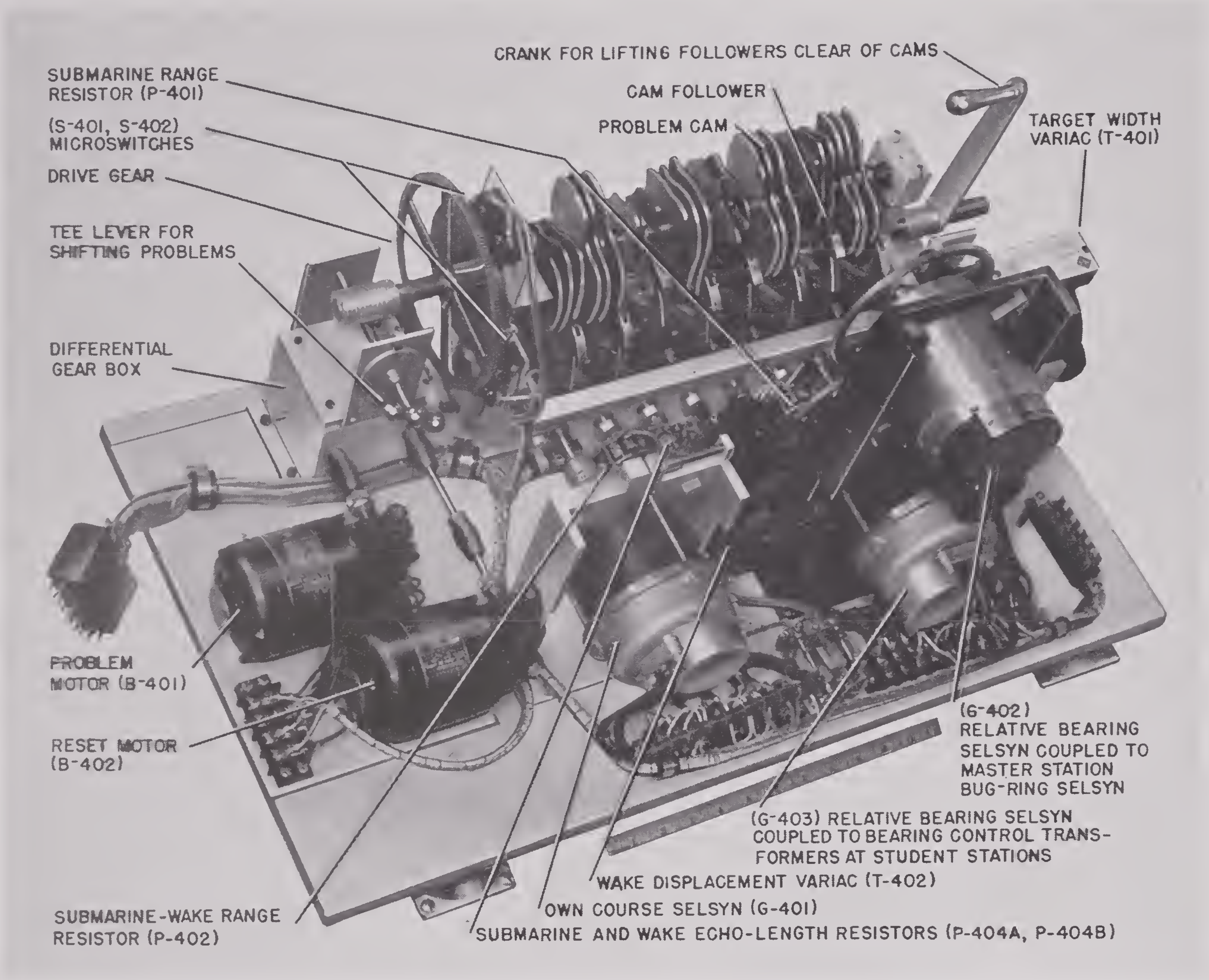

CRANK FOR LIFTING FOLLOWERS CLEAR OF CAMS
SUBMARINE RANGE RESISTOR (P-401)
CAM FOLLOWER
(S-401, S-402) MICROSWITCHES
PROBLEM CAM
TARGET WIDTH VARIAC (T-401)
DRIVE GEAR
TEE LEVER FOR SHIFTING PROBLEMS
DIFFERENTIAL GEAR BOX
PROBLEM MOTOR (B-401)
RESET MOTOR (B-402)
(G-402) RELATIVE BEARING SELSYN COUPLED TO MASTER STATION BUG-RING SELSYN
(G-403) RELATIVE BEARING SELSYN COUPLED TO BEARING CONTROL TRANSFORMERS AT STUDENT STATIONS
WAKE DISPLACEMENT VARIAC (T-402)
OWN COURSE SELSYN (G-401)
SUBMARINE-WAKE RANGE RESISTOR (P-402)
SUBMARINE AND WAKE ECHO-LENGTH RESISTORS (P-404A, P-404B)

FIGURE 17. Program generator, front view.

selsyns of all the student stations. G-401 is termed the own-course selsyn.

The second cam follower turns the variable resistor P-402 that controls the time delay corresponding to the submarine wake range.

The third cam follower turns the two variable resistors P-404A and P-404B that respectively control the pulse lengths corresponding to the duration of the submarine echoes and wake echoes. In an actual attack, these durations depend upon the aspect of the submarine.

The fourth cam follower turns the wake displacement Variac T-402. Inasmuch as the fixed connection on the Variac is a center tap, the variable tap can supply the simulated transducers with voltages of both polarities to correspond to right or left displacements of the wake echo from the submarine echo.

The fifth cam follower turns the variable potentiometer P-406, which varies the echo oscillator frequency in simulation of doppler.

The sixth cam follower turns the variable resistor P-401, which controls the time delay corresponding to the submarine range.

The seventh cam follower turns two relative-bearing selsyns: G-402 is coupled electrically to the bug-ring selsyn on the master-station bearing dials, to indicate the center bearing of the submarine; G-403 is coupled electrically to the bearing control transformers of the student stations. In order to develop a minimum bearing voltage in the rotor of his control transformer (on-target condition), each student must orient his rotor (his "projector") to correspond to the position of the G-403 rotor. The bearing voltage is fed into the grading-recorder circuit to indicate whether the student is on target, and into the simulated transducer to control echo intensities and BDI indications.

The eighth cam follower turns the target width Variac T-401. This Variac controls the amplitude of the 60-c voltage applied to the wake displacement Variac T-402 and to the rotor of the relative bearing selsyn G-403. Hence, as voltage output in the Variac increases, there is a simultaneous increase in the apparent angular displacement of the wake from the submarine, and in the apparent width of the target.

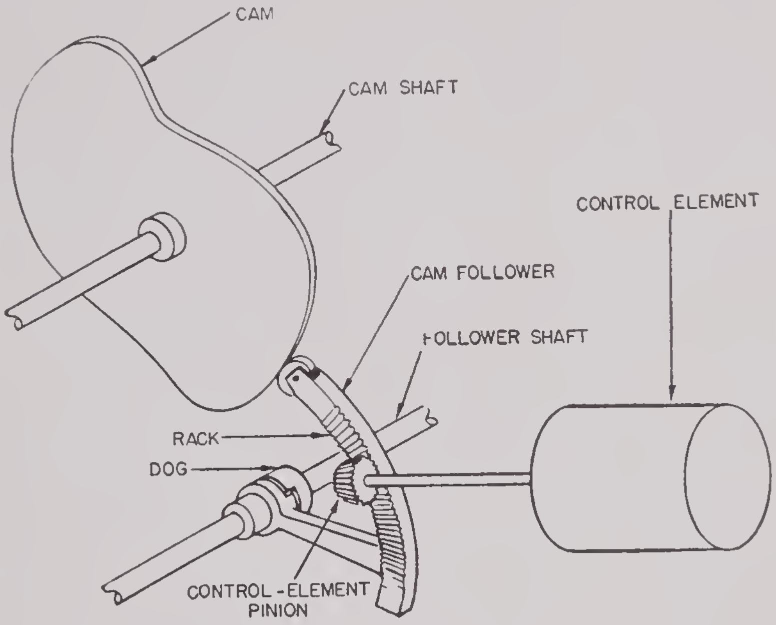


FIGURE 18. Cam and follower mechanism.

SIMULATED TRANSDUCER

The simulated transducer (Figure 15) at each student station receives four input voltages: (1) the submarine-echo voltage from the follower chassis, (2) the submarine wake-echo voltage from the follower chassis, (3) the bearing voltage from the student station bearing control transformer, (4) the wake-displacement voltage from the problem generator. The two echo voltages enter the simulated transducer with all the attributes appropriate to the problem in hand except those controlled by the bearing of the target. It is the function of the simulated transducer to modify the echoes in accordance with the bearing voltage and the wake displacement voltage.

The simulated transducer consists of two circuits, which are identical except for input connections. On the diagrams, these circuits are arranged one above the other; the top circuit modifies the submarine echo, and the bottom circuit modifies the submarine wake echo. Each of the two circuits has two identical channels. Each channel consists of a phase-sensitive amplifier, a low-pass filter, a variable gain amplifier, and a phase-shifting network. The phase-sensitive amplifier produces an output voltage the magnitude of which depends on the phase and magnitude of the bearing voltage in the top circuit and on the phase and magnitude of the bearing voltage plus the wake-displacement voltage in the bottom circuit. The output of the phase-sensitive amplifier is fed through the filter to eliminate the a-c component, and the remaining d-c voltage is applied as bias to the grid of the variable-gain amplifier. Also applied to this grid is the submarine echo or the submarine wake echo. Variable gain is attained by operating the amplifier near the cutoff bias and by chopping off more and more of the signal wave as the bias is increased. Distortion is eliminated, in the present application, by resonant circuits in the student's receiver-amplifier. The output of the variable-gain amplifier is applied to a phase-shifting network that gives the echo the same phase characteristics as it would have in coming from the right or left half of a split transducer.

The bearing voltage is applied to the simulated transducer through S-201 and R-244. The phase-sensitive amplifiers of the submarine echo channels are excited directly by this voltage through R-202 and R-203. The wake-displacement voltage is applied to the simulated transducer through S-201 and T-201. By a series connection, this voltage is added to the bearing voltage; and the sum excites the phase-sensitive amplifiers of the submarine wake-echo channels through R-212 and R-213.

A 60-c reference voltage is applied to the four cathodes of the phase-sensitive amplifiers from T-202. The connections are so made that the cathode potentials in each pair of amplifiers are 180 degrees out of phase. Thus, in the submarine echo circuit, when the student, by training slightly off target, excites the amplifier grids with the 60-c bearing voltage, the effect of the reference voltage is to increase the plate current in one triode and to reduce it in the other, an effect which in turn increases the output of the variable-gain amplifier in one channel and reduces it in the other. By training off the target in the opposite direction, the high-gain and low-gain channels are reversed.

The plates of the variable-gain amplifiers in the submarine echo circuit are connected to the opposite ends of the phase-shifting network, consisting of C-216, R-241, R-242, and C-215, which feeds its output into the primaries of T-205 and T-203. In the secondary circuit of one of the latter transformers, the echo tone from one channel is advanced in phase by approximately 45 degrees; in the other secondary, the echo tone from the same channel is retarded in phase by a similar angle. The echo tone from the second channel is also advanced and retarded respectively, by approximately 45 degrees; only now the leading and lagging secondaries have been reversed. In other words, the phase angles of the two channel voltages are of opposite sign in each secondary, and as the magnitudes of the two channel voltages approach each other in value, the phase angle of the resultant voltage approaches zero. The BDI circuits of the student's stack, to which the secondaries of T-205 and T-203 connect, are designed to interpret a deviation of the resultant voltage angle from zero as an off-target indication. Such an off-target indication will result whenever the bearing voltage from the bearing-control transformer is other than zero.

The submarine wake-echo circuit of the simulated transducer functions in exactly the same manner as the submarine echo circuit. The two differ only in their input voltages. As previously mentioned, the input to the submarine wake-echo circuit consists of the sum of the bearing voltage and the wake-displacement voltage, instead of the bearing voltage alone. Hence, in order that the transducer may give an on-wake indication, the student must train the bearing-control transformer off the target until the bearing voltage is equal and opposite to the wake-displacement voltage, thus producing the necessary zero sum voltage.

A type 6AF6 double indicator tube (V-207 and V-206) is used in each transducer circuit to show balance. After adjustment is complete, the indicator tubes are pulled out of the sockets, and the circuits are operated without them.

The discussion of simulated transducer operation has thus far involved only on-target or slightly off-target situations. As the student trains more and more off the target, the outputs of both channels in each circuit are reduced until they are cut off.

Water noise, surface wake echoes, reverberations, and own-ship's propeller beats are mixed with the submarine and submarine-wake echoes in the output circuit of the simulated transducer. These are all nondirectional sounds, except the own-ship's propeller beats, which are given a directional characteristic by a student-station unit. The potentiometer P-107 is coupled mechanically to the stack training mechanism, to pass a maximum signal when the relative bearing of the imaginary projector is slightly less or slightly greater than 180 degrees.

INDICATORS

The instructor has before him four types of indicators to show the progress of the problem and the students' reactions: (1) pilot lights, (2) bearing dials, (3) bearing indicators, and (4) a grading recorder.

There are three pilot lights—red, blue, and green. The red pilot light (I-601) is actuated by the start button of the power switch. The blue or green light (I-603 or I-602) indicates whether the first or second of the pair of cam problems ("attack" or "reattack") is in progress.

Each conventional bearing dial consists of a compass card in the center, a bug ring, and a stationary relative-bearing scale on the outside. The bug indicates the true and relative center bearings of the submarine from the ASW vessel. Each of the ten bearing indicators (B-601 to B-610) has a bearing scale and a pointer, which show the relative bearing of the student's projector.

The grading recorder is adapted from a Sangamo tactical range recorder by the substitution of a new stylus assembly and a new gear and motor assembly. Figure 19 is a photograph of the recorder, and Figure 20 is a sketch showing the type of record produced by the device. Each of the ten student stations is represented on the recorder by three fixed styli. The center stylus marks the paper at the moment during each target echo when contact K-101B on the keying chassis closes. This echo record is independent of the students' actions. The right and left styli mark the paper when the student trains right and left respectively, from the center bearing of the target. The marking voltages for these styli are received from a student-station follower unit, which is excited by the bearing control transformer voltage.

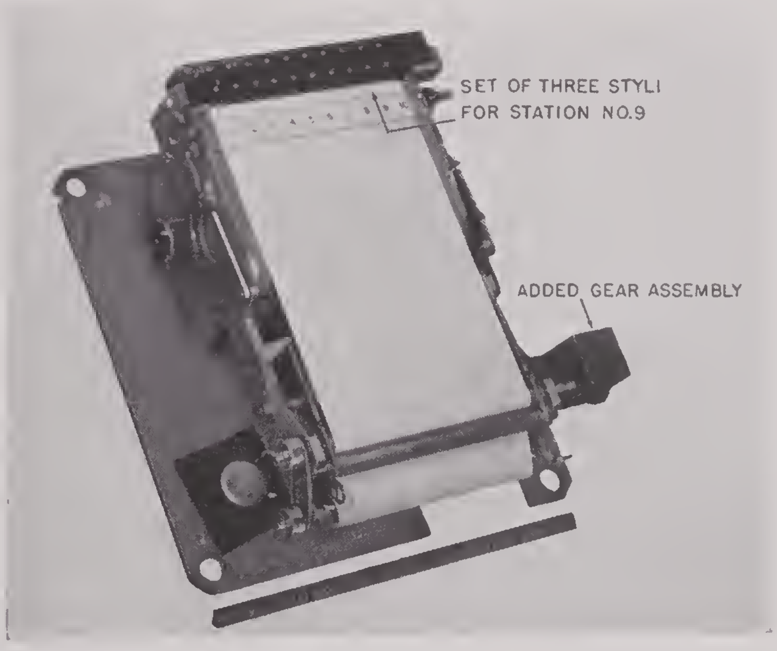

SET OF THREE STYLI FOR STATION NO.9
ADDED GEAR ASSEMBLY

FIGURE 19. Grading recorder (adapted tactical range recorder).

6.18.1 Means of Coupling Stack Training Mechanisms to the GOT

In the previous sections covering the technical description of the GOT, references were made to the coupling of four GOT elements to the training mechanism of each student stack. These elements are (1) the bearing control transformer, (2) the bug on the student's bearing dials, (3) the indicator-transmitter potentiometer, and (4) the propeller-beat potentiometer.

In the QGB, the bearing control transformer is the synchro that is already connected mechanically to the training handwheel; thus the only modification necessary is to change its wiring. A simple gear train is installed to couple the shaft of the control transformer to the other three elements. The student, therefore, drives all four units by the torque that he applies to the handwheel.

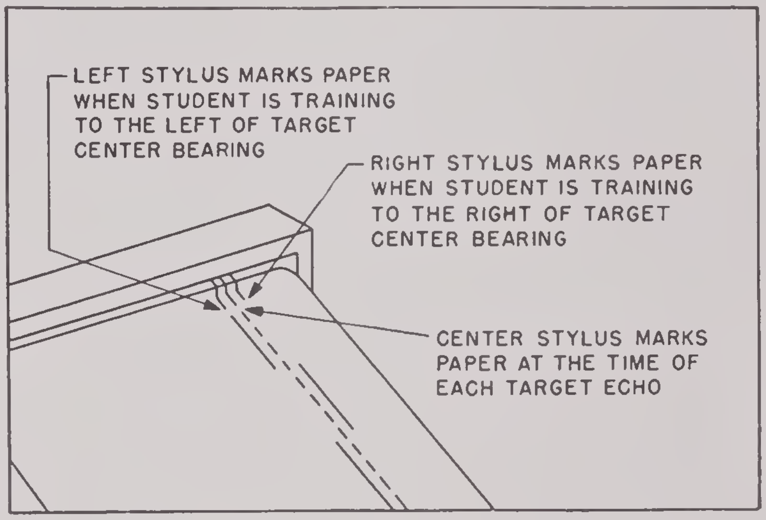

LEFT STYLUS MARKS PAPER WHEN STUDENT IS TRAINING TO THE LEFT OF TARGET CENTER BEARING
RIGHT STYLUS MARKS PAPER WHEN STUDENT IS TRAINING TO THE RIGHT OF TARGET CENTER BEARING
CENTER STYLUS MARKS PAPER AT THE TIME OF EACH TARGET ECHO

FIGURE 20. Typical record made by the grading recorder.

In the QJB, an adapter unit is installed on the same chassis as mounts the simulated transducer and the grading-recorder follower unit. The drive selsyn of the adapter unit is coupled electrically to the training mechanism of the QJB and drives the bearing control transformer, the indicator-transmitter potentiometer, and the propeller-beat potentiometer through a train of gears. Indirectly, the drive selsyn also moves the bug on the student's bearing dials by driving a 1-G selsyn. The 1-G selsyn is coupled electrically to a control transformer, which is part of the servo system that positions the bug.

Chapter 7

RECORDER OPERATOR TRAINERS

THREE DEVICES WERE developed to assist in training range recorder operators: the *elementary range recorder teacher,* the QFL *tactical range recorder teacher,* and the *recorder trace projector.* All three are covered in this chapter.

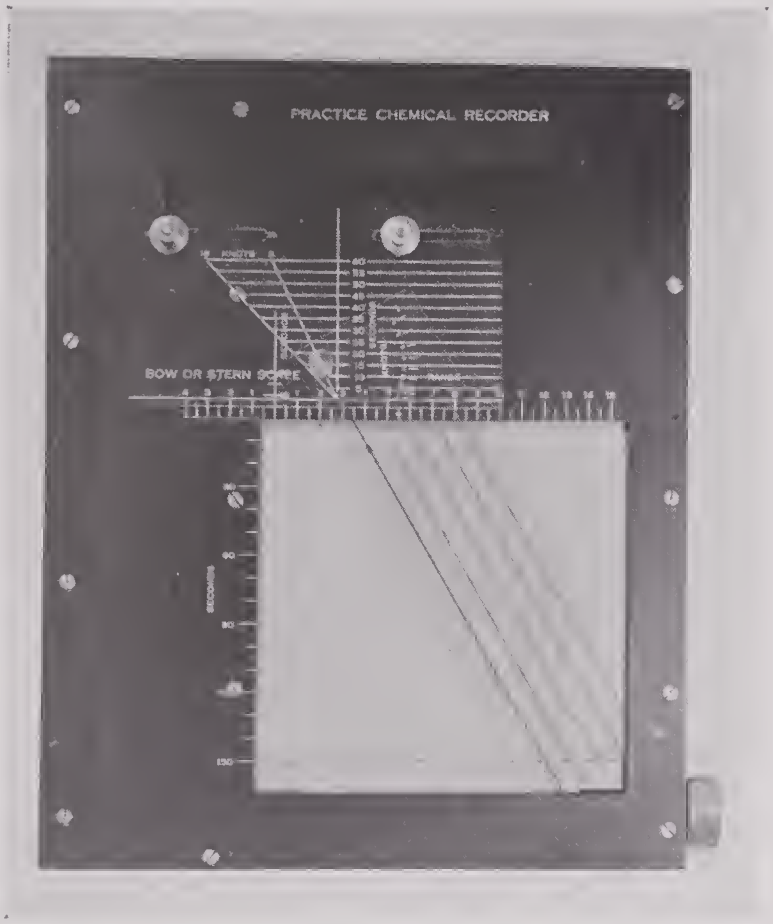


FIGURE 1. Elementary range recorder teacher.

Following the development of the chemical sound-range recorder, the need for some simple means of giving elementary instruction in the operation of this device became apparent. As a stopgap measure, the elementary range recorder teacher was designed, and 25 units were constructed and delivered to the West Coast Sound School [WCSS].

Figure 1 shows the mockup of the chemical sound range recorder face which constitutes the elementary range recorder teacher. A printed trace recorded at sea is inserted in the device, and the dummy controls shown in the figure give the student practice in manipulating the plotter bar, setting the adjusters of the bow or stern scale and the ship's speed scale, determining ranges and range rate, and calling firing time.

Although students can get a general idea of the elementary operations of the chemical sound range recorder from working with this teacher, its chief drawback is that it does not drill the trainee in routines exactly duplicating those which a sound range recorder operator should perform automatically. Since the dummy controls in the mockup are differently placed from those in a standard chemical sound range recorder, the student who has practiced on the teacher must re-learn the routine of operating these controls when he transfers from the teacher to an actual recorder.

Elementary Range Recorder Teacher

The elementary range recorder teacher provides elementary training in the use of the chemical sound range recorder. Essentially it is a mockup of a chemical sound range recorder face which has been considerably simplified. It includes range and speed scales, a plotter bar, and a set of printed "sea" recordings, furnished with each unit. The bow or stern scale and the ship's speed scale are placed above and slightly to the left of the range scale, plotter bar, and plotter bar extension, instead of in the lower right-hand corner, as in the operational sound range recorder. The adjusters for these scales, together with the plotter bar control, are the only controls embodied in the mockup. The printed copies of different types of traces recorded at sea may be inserted in the "window" so that the student may practice interpreting traces, manipulating the plotter bar and its extension in line with the traces, and determining range rate and firing time. This training device was developed by UCDWR.

7.1 INTRODUCTION

Prior to the development of the QFL tactical range recorder teacher, trainers for echo-ranging equipment had used only electronically produced sounds. Such simulated sounds, particularly reverberation, had never been truly realistic. Since sonar operators using later models of sonar gear do not hear the outgoing ping, they must recognize doppler effects by comparing the frequencies of the submarine echo and of the reverberation and of the wake echo.

The search for greater realism of reproduced signals, echoes, and reverberation in land-based trainers led to the development of the QFL tactical range recorder teacher, using phonograph recordings of echo-ranging sounds made under operating conditions at sea. The recordings provide signals which produce traces in five or more range recorders at the same time; accompanying sounds of echoes and reverberations are heard through a loudspeaker. A student stationed at each recorder manipulates the recorder controls and interprets the traces exactly as he would in an actual attack on a submarine.

The complete equipment is shown in Figure 2. In the center is an amplifier control unit in which are mounted the record playback and the chassis carrying the various circuits for keying, trace control, and speech amplifying. The amplifier drives five sound range recorders and also feeds the signals into the loudspeaker. The power source for the amplifier is a 110-volt, 60-c outlet. Figure 3 is a complete wiring schematic.

Shelves are provided in the lower part of the amplifier control unit cabinet for the records used with the equipment. There are 34 of these. One is a sensitivity adjustment record, used to test the equipment before putting it into regular operation. The remaining 33 are recordings of sound signals made during practice attack runs at sea. An instruction manual completes the QFL equipment.

QFL Tactical Range Recorder Teacher

The QFL tactical range recorder teacher, developed by CUDWR-NLL, consists of a series of five or more sound range recorders operating on signals from phonograph recordings; an amplifier control unit in which are mounted the record playback and the chassis carrying the various circuits for keying, trace control, and speech amplifying; and a loudspeaker.

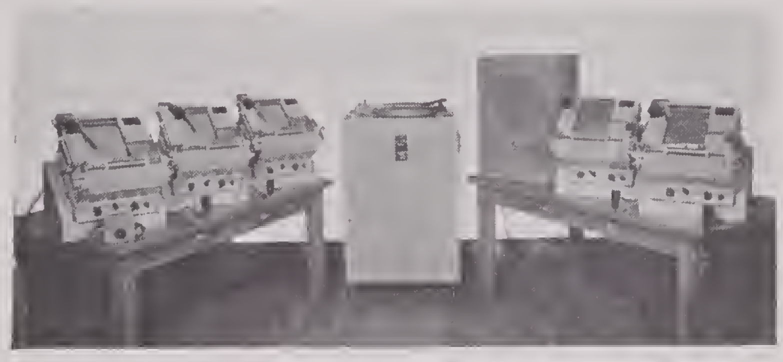


FIGURE 2. QFL tactical range recorder teacher.

7.2 TECHNICAL DESIGN

Three different models of the QFL tactical range recorder teacher were designed before the problems posed were satisfactorily met. The modifications made were chiefly in the amplifier control unit.

AMPLIFIER CONTROL UNIT

Model 1. The first experimental QFL model drove only one sound range recorder. Signals from a phonograph recording on the turntable were fed via a magnetic pickup, through an input transformer and a two-stage amplifier to an output transformer. The output of this transformer went to a power amplifier, which supplied the loudspeaker and the trace circuit of the recorder. In the keying circuit, the signal voltage was rectified and brought to a thyratron with associated relays. The initial burst of reverberation energized one relay through the thyratron, engaging the clutch in the recorder and causing the stylus to be drawn across the paper. When the stylus reached the flyback contacts on the recorder, a second relay was energized, opening the plate circuit of the thyratron and thus causing the recorder clutch to disengage.

This keying arrangement proved unsatisfactory. Often the initial burst of reverberation was too weak to operate the thyratron. Sometimes extraneous noise impulses caused keying at the wrong time. Therefore, only one experimental model of this type was constructed.

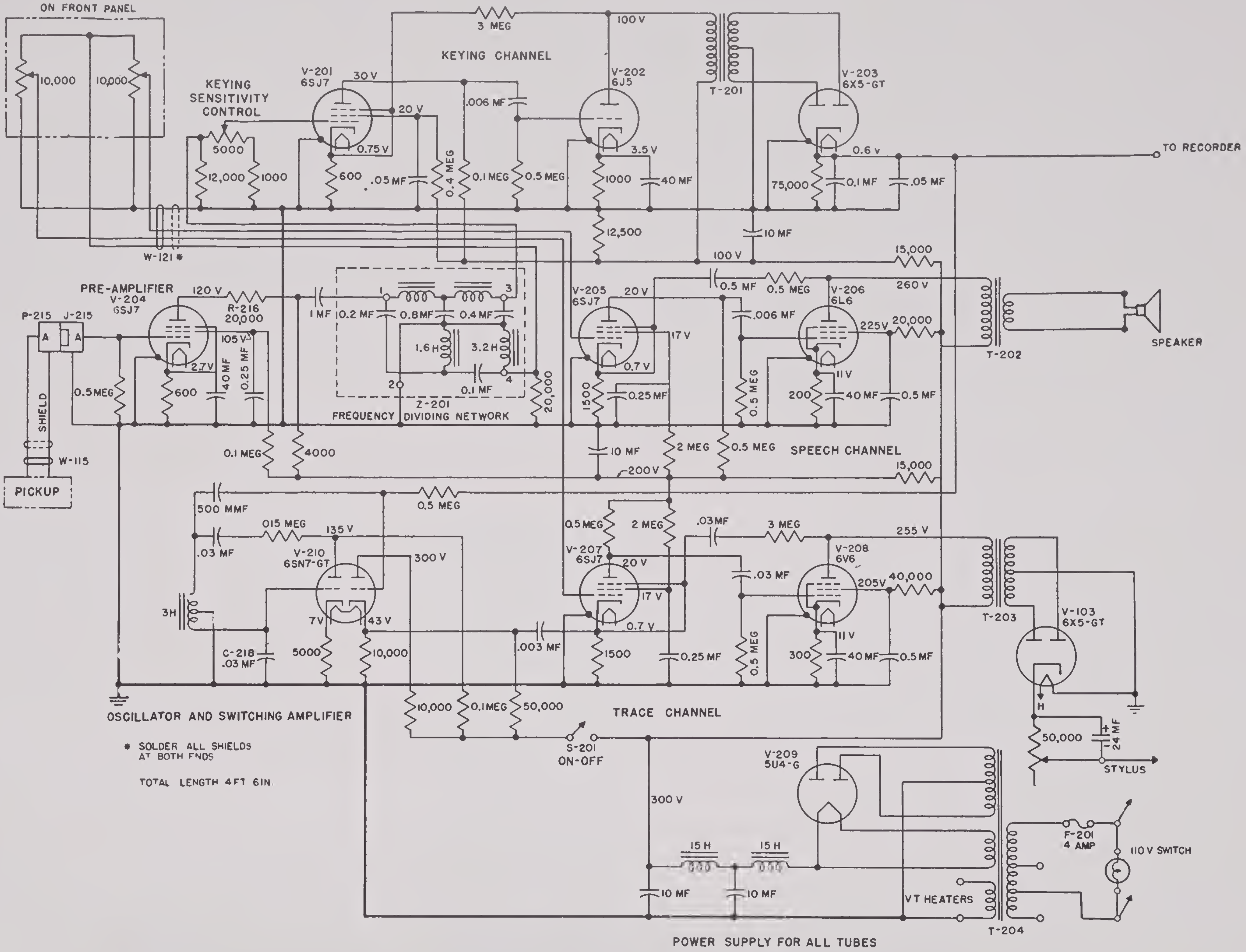

ON FRONT PANEL
10,000
10,000
KEYING SENSITIVITY CONTROL
5000
12,000
1000
W-121 *
KEYING CHANNEL
3 MEG
100 V
V-201 6SJ7
30 V
20 V
0.75 V
600
.05 MF
0.4 MEG
0.1 MEG
0.5 MEG
.006 MF
V-202 6J5
3.5 V
1000
40 MF
12,500
T-201
V-203 6X5-GT
0.6 v
75,000
0.1 MF
.05 MF
10 MF
TO RECORDER
PRE-AMPLIFIER V-204 6SJ7
P-215
J-215
A
A
SHIELD
W-115
PICKUP
120 V
R-216 20,000
105 V
2.7V
600
40 MF
0.25 MF
0.5 MEG
1 MF
0.2 MF
0.8 MF
0.4 MF
1.6 H
3.2 H
0.1 MF
1
2
3
4
Z-201
FREQUENCY DIVIDING NETWORK
20,000
0.1 MEG
4000
100 V
15,000
V-205 6SJ7
20 V
17 V
0.7 V
1500
0.25 MF
10 MF
-200 V
2 MEG
0.5 MEG
0.5 MF
0.5 MEG
.006 MF
V-206 6L6
260 V
225V
20,000
11 V
200
40 MF
0.5 MF
0.5 MEG
SPEECH CHANNEL
15,000
T-202
SPEAKER
500 MMF
0.5 MEG
.03 MF
015 MEG
135 V
V-210 6SN7-GT
300 V
3H
7V
43 V
C-218 .03 MF
5000
10,000
OSCILLATOR AND SWITCHING AMPLIFIER
• SOLDER ALL SHIELDS AT BOTH ENDS
TOTAL LENGTH 4FT 6IN
0.5 MEG
2 MEG
V-207 6SJ7
20 V
17 V
0.7 V
.003 MF
1500
0.25 MF
.03MF
3 MEG
V-208 6V6
255 V
.03 MF
205V
40,000
11 V
300
40 MF
0.5 MF
0.5 MEG
10,000
0.1 MEG
50,000
TRACE CHANNEL
S-201 ON-OFF
T-203
V-103 6X5-GT
H
50,000
+ 24 MF -
STYLUS
V-209 5U4-G
300 V
15 H
15 H
10 MF
10 MF
VT HEATERS
T-204
F-201 4 AMP
110 V SWITCH
POWER SUPPLY FOR ALL TUBES

FIGURE 3. Wiring schematic for QFL.

Model 2. This model employed a 75-c keying tone, instead of the initial burst of reverberation, to key the recorders. The 75-c tone was adopted because it could readily be filtered out of the sound and trace circuits without causing any noticeable differences in either the sounds or the traces. Also, the amplitude of a tone of this frequency remains relatively constant on a recording, in spite of repeated playing.

Signals from the magnetic pickup in this model go through an amplifier to a dividing network having a crossover frequency of 200 c. Components above 200 c are fed through a power amplifier to the loudspeaker and recorder trace circuits. Components below 200 c, including the 75-c keying tone, go through a two-stage amplifier to a full-wave rectifier. The output of this rectifier energizes the thyratron and relays, as in Model 1.

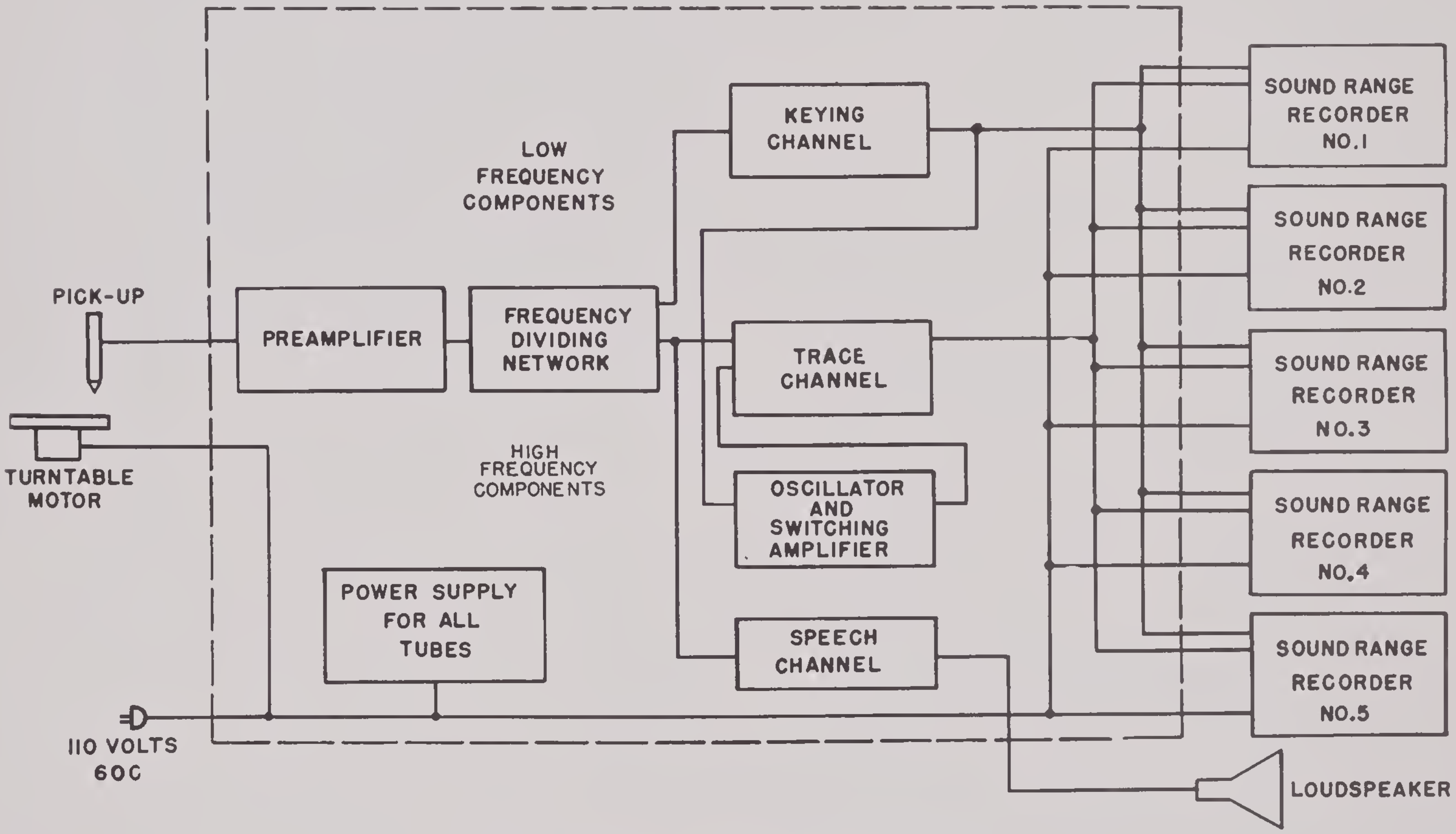

LOW FREQUENCY COMPONENTS
KEYING CHANNEL
SOUND RANGE RECORDER NO.1
SOUND RANGE RECORDER NO.2
SOUND RANGE RECORDER NO.3
SOUND RANGE RECORDER NO.4
SOUND RANGE RECORDER NO.5
PICK-UP
PREAMPLIFIER
FREQUENCY DIVIDING NETWORK
TRACE CHANNEL
TURNTABLE MOTOR
HIGH FREQUENCY COMPONENTS
OSCILLATOR AND SWITCHING AMPLIFIER
POWER SUPPLY FOR ALL TUBES
SPEECH CHANNEL
110 VOLTS 60C
LOUDSPEAKER

FIGURE 4. Block diagram of QFL Model 3.

This keying arrangement proved dependable. Five units of Model 2 were made and put into service at antisubmarine warfare [ASW] training centers.

Model 3. The most important change initiated in Model 3 (see block diagram, Figure 4) was the elimination of the keying relays. Advantage was taken of the thyratron in the recorders to provide direct keying from the full-wave rectified keying tone. Separate level adjustments were added for the three major channels. Minor circuit changes made it possible to add more recorders in multiple, if desired.

An oscillator and switching channel was also added to permit the printing of a variable length trace as the stylus begins to move across the paper. This feature simulates the printed signal trace which is used on some models of the sound range recorder. Model 3 served as a manufacturer's prototype for the production design of the amplifier control units.

SOUND RANGE RECORDERS

The sound-range recorders attached to the QFL equipment are the same, with slight modifications, as those in operational use. The first five equipments (Model 2) were designed to operate with Model CAN-55100 Sangamo sound range recorder. Because later recorder models, when used with Model 3 QFL equipment, provided less contrast between different parts of the trace than had been obtained with the CAN-55100 recorder, the traces were more difficult to interpret. A special recorder was therefore developed for use with the QFL equipment.

To adapt the recorder for use with the QFL teacher, the wiring was changed slightly so that the keying of the stylus is controlled by an external 75-c pulse, whereas in recorders used aboard ship the keying is automatic and supplied from circuits within the recorder itself. An extra stylus is mounted in a stationary position at the extreme left of the bars which carry the moving stylus. This extra stylus produces a dotted line along the left edge of the paper to mark the beginning of the simulated outgoing signal.

Phonograph Recordings

Several hundred recordings were made of the sound signals received by echo-ranging surface craft through their echo-ranging equipment during practice attacks on target submarines under a wide variety of attack conditions. This material was edited to produce the QFL training series of 34 recordings which are arranged in order of increasing difficulty.

The series is designed so that, if necessary, it can be used without a trained instructor. It includes a sensitivity adjustment record for adjusting the equipment before beginning the training session. The remaining 33 records in the series contain the sounds received by ASW sonar equipment and the injected 75-c pulses for keying the recorders; they also give verbal descriptions and instructions. The drills provided by the recordings include training in recognition of different types of target inclination by the nature of the echo (beam, quarter, and bow targets), discrimination between target and wake echoes, doppler recognition, knuckle wake recognition, in addition to practice in setting the firing time analyzer and determining range rate and firing time. A full description of the QFL equipment may be found by consulting the bibliography.[1]

7.3 CONCLUSION

Reports on the 63 QFL equipments which were constructed and distributed emphasized repeatedly their service as a training device. Their value lies especially in the fact that they closely simulate actual operating conditions and provide drills in order of increasing difficulty. A slightly modified version of the QFL equipment was developed for use in submarine training activities to teach the operation of the sound range recorder as part of torpedo detection gear.

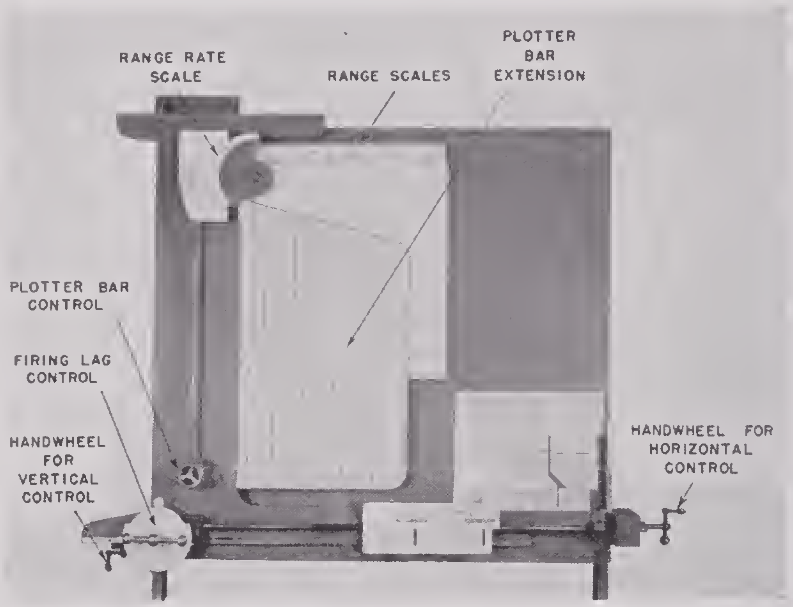


FIGURE 5. Screen of recorder trace projector.

Recorder Trace Projector

The recorder trace projector, developed by CUDWR-NLL for classroom demonstration of typical problems and conditions encountered in the operation of the sound range recorder, consists of a screen, projector, and a sound range recorder arranged so that the moving recorder traces may be projected onto the screen. The source for producing the recorder traces is a phonograph record in a QFL tactical range recorder teacher or in a QFA (Sangamo) attack teacher. The screen is a reproduction of the analyzer and control mechanism of the sound range recorder enlarged to five times its original size and mounted vertically on a board.

7.4 INTRODUCTION

The recorder trace projector was developed originally to meet a need expressed by the Submarine Chaser Training Center in Miami, Florida, for a means of demonstrating the operation of the sound-range recorder in the classroom.

7.5 DESCRIPTION

SCREEN

The screen is a reproduction, with a few modifications, of the cover plate, range scales, and recording paper of a recorder. The blackboard and the framework on which the moving parts of the screen are mounted are of wood; the plotter-bar extension is of sheet metal, with painted lines to simulate those on the transparent plotter-bar extension of an actual recorder. Figure 5 shows the screen with the plotter bar in the zero range rate position. For the convenience of the instructor, a handwheel on an extension reaching to one lower corner of the blackboard is substituted for the hand knob used to control the plotter bar of an actual recorder. This is the chief modification in the face of the recorder in this equipment. The handwheels shown at the lower left-hand and right-hand corners control the vertical and horizontal adjustments of the plotter-bar "zero." Vertical movement of the framework is facilitated by a counterweight which slides in a housing installed on the rear of the screen.

The recorder scales and adjusters relating to such factors as ship's speed, depth charge or projectile sinking time, and distance from the projector to the stern, which are incorporated in an actual sound range recorder, are also duplicated on the screen.

PROJECTOR, RECORDER FRAMEWORK, AND STAND

A commercial projector (Bausch & Lomb Balopticon) is modified for installation over a sound-range recorder so that range traces appearing on the recording paper are projected on to the screen. The modification consists of the removal of the lower structure normally used with this projector and relocation of the switch and blower so that the platen aperture can be mounted on the hinged cover of a framework designed to house the sound-range recorder. The framework cover and projector together are raised to a vertical position, as shown in Figure 6, to permit installation of the recorder. When the recorder is in place with its cover swung into the open position, also shown in Figure 6, the projector is lowered so that it fits snugly over the exposed recorder paper. With the projector in this position, the platen aperture admits an image of the upper portion of the recorder tracing mechanism, including the flyback pointer, the recording paper, and the short-range scale (in models in which this scale is not on the cover).

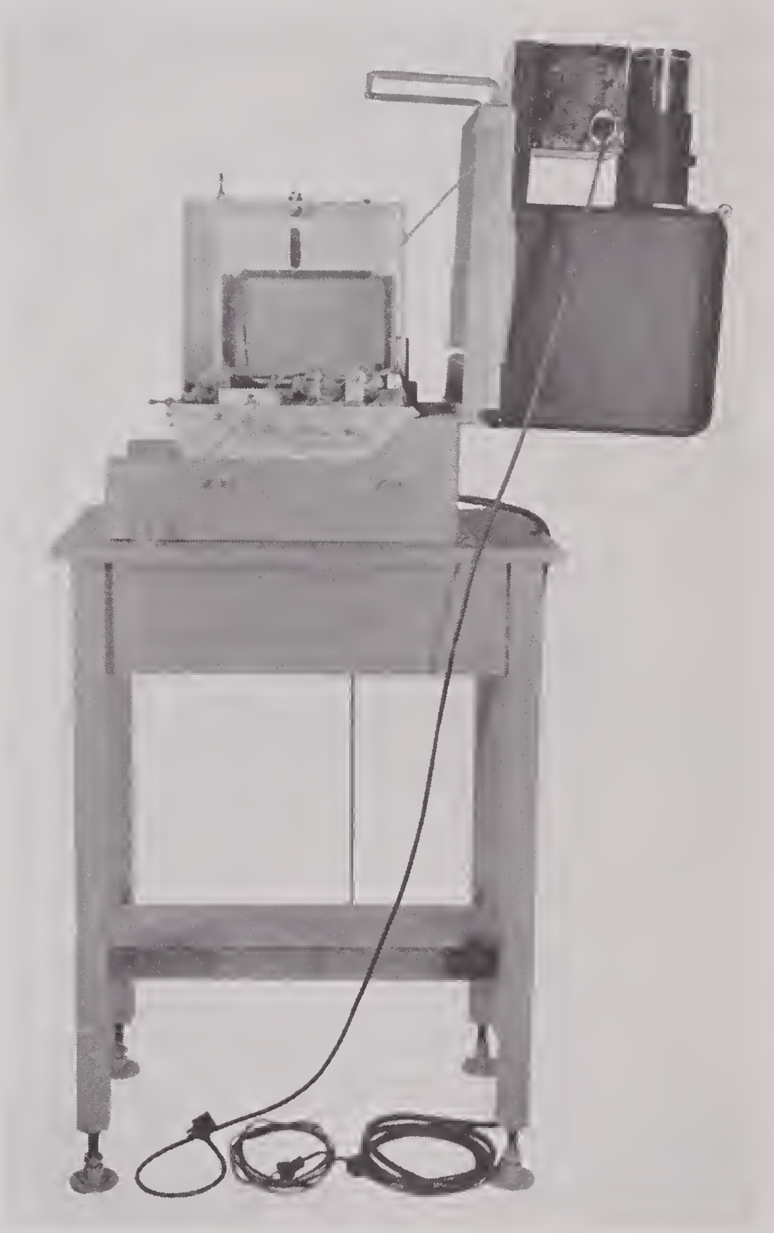


FIGURE 6. Projector with framework cover opened to permit installation of recorder.

Adjustment of the position and of the focus and angle of the projector are made by means of adjustable feet and a jack-screw arrangement on the stand, to bring the "zero-zero" of the projected recorder scales into register with the corresponding point on the screen.

7.6 CONCLUSION

For the purpose of instructing students in the maneuvers of an attacking vessel and a submarine through the interpretation of recorder traces, the recorder trace projector can be used in conjunction with the recorder of an antisubmarine attack teacher such as the QFA series underwater sound attack teachers. With such an arrangement, the movements of the submarine and of the attacking vessel on the QFA screen can be observed and firing time demonstrated in relation to the projected traces of the recorder. The equipment may also be used with the recorders of the QFL tactical range recorder teacher.

Any further development work on this device might well be directed toward strengthening the projected recorder traces so that they may be more easily read.

Chapter 8

CLASSROOM ATTACK TEACHER MODIFICATIONS

As LABORATORY developments carried on under Division 6 added new or improved features to sonar gear, there was an interim need for devices to adapt early models of the Sangamo attack teacher for use with these features. *Operator training equipment,* Model 4 (OTE-4), described in this chapter, is such an auxiliary device.

Minor but useful additions made to the attack teacher under the program of Division 6 are also covered here. These are the *assisting ship projector,* the *attack teacher azimuth grid,* and the *depth charge pattern recorder.*

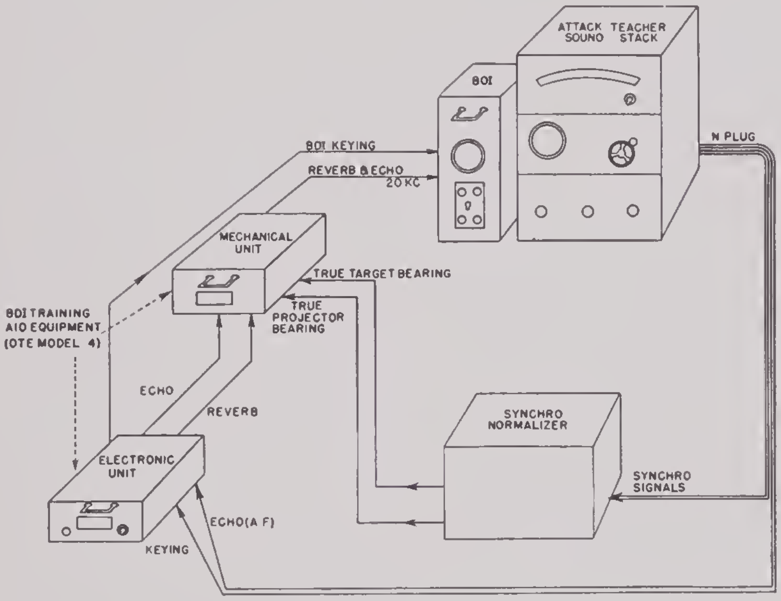


FIGURE 1. Diagram of OTE-4 connections with normalizer, attack teacher, and BDI .

Operator Training Equipment, Model 4 (OTE-4)

Operator training equipment, model 4 (OTE-4), developed by HUSL is an auxiliary device for adapting early models of the Sangamo attack teacher for use in BDI instruction. The equipment generates signals suitable for direct application to standard BDI units and produces reverberation and bearing deviation indications that are synchronized with the audible signals generated by the attack teacher. It includes a BDI 20-kc generator whose operation is coordinated with that of the 0.8-kc attack teacher, projector simulator coils for providing right-left-center indications on the BDI screen, and a synchro-normalizer for conversion of the attack teacher synchro generators.

8.1 INTRODUCTION

Three units of OTE-4 were constructed to fill an interim need for a BDI training device to be used with the Sangamo attack teacher. In designing such a device, three principal problems had to be solved. First, since Models QFA-2 and QFA-3 of the attack teacher generate signals photoelectrically at 800 c, whereas the standard BDI is built for an input of 18 to 24 kc, it was necessary to design a 20-kc generator for the BDI and then devise some means of coordinating its operation with that of the attack teacher. Second, a means had to be provided for producing the proper right-center-left indications on the BDI screen to correspond to the deviation of projector bearing from actual target bearing. Third, a synchro-normalizer was needed to convert the 60:1 ratio operation of the attack teacher synchro-generators to the 1:1 ratio of operation of the OTE-4 unit.

In the solution of these problems, the *projector simulator* [PS] coils, as in other OTE developments, constituted the most important component of the equipment. For a detailed discussion of the theory of PS coils, the reader is referred to the section on the artificial sonar projector in Chapter 11 of this volume.

Following delivery of modernized attack teachers with built-in BDI features, the OTE-4 development program was abandoned.

8.2 DESCRIPTION OF EQUIPMENT

OTE-4 consists of two units, one electronic and one mechanical. The six synchros comprising the normalizing device are housed in a special cabinet and need not be considered an integral part of the OTE-4, since the normalizer may be used to perform a similar function in other devices. Figure 1 shows the relationship of the various components when connected to the attack teacher.

The mechanical unit, shown in Figure 2, contains the reverberation phase-and-amplitude modulator assembly, the PS coils which simulate bearing deviation, and the echo and reverberation network. A circuit diagram for the mechanical unit is shown in Figure 3.

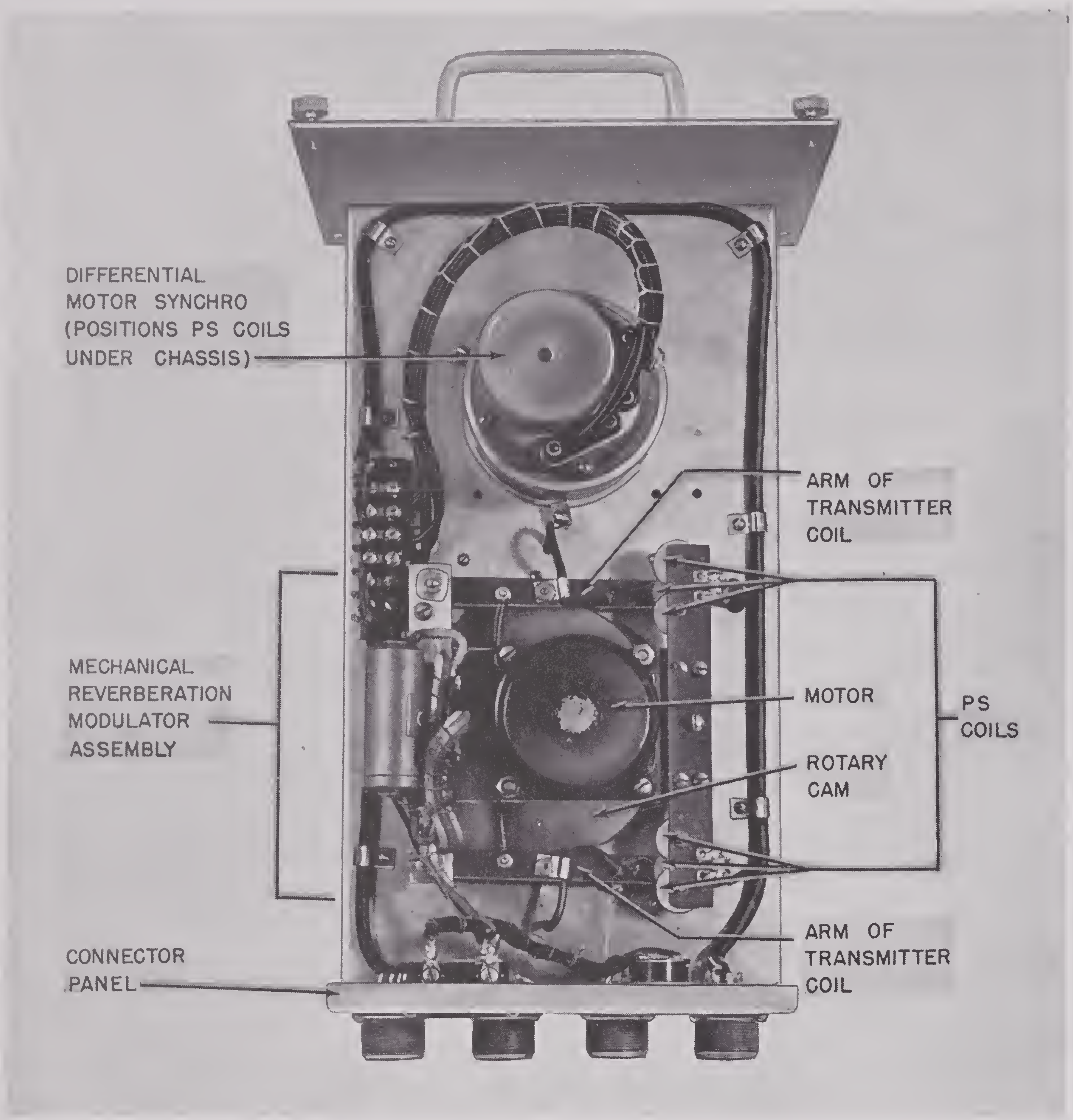

DIFFERENTIAL MOTOR SYNCHRO (POSITIONS PS COILS UNDER CHASSIS)
ARM OF TRANSMITTER COIL
MECHANICAL REVERBERATION MODULATOR ASSEMBLY
MOTOR
PS COILS
ROTARY CAM
ARM OF TRANSMITTER COIL
CONNECTOR PANEL

FIGURE 2. Mechanical unit of OTE-4, top view.

All the electronic circuits, including the noise-generating and synchronizing circuits, are contained in the electronic unit, a functional diagram of which is shown in Figure 4 and a schematic in Figure 5. The synthesized signals generated in the electronic unit are controlled by means of the keying pulse and echo signal furnished by the attack teacher, and are thus synchronized with the audible signals from the latter.

BDI Simulation

The relative positions of the PS coils under the chassis of the mechanical unit (shown in Figure 3) determine whether the BDI trace indicates right, left, or center bearing of the projector with respect to the target. The simplest mechanical arrangement for achieving realistic simulation of BDI operation with the use of PS coils proved to be that illustrated in Figure 6. The coils labeled 1, 2, and 3 are fixed in position; coil 4 is attached to a rotor arm so that, as the arm swings, this coil moves back and forth under the fixed coils. The circuits are such that when the attack teacher projector is exactly on center target bearing, the movable coil is directly under fixed coil 1 and the BDI trace indicates center bearing. For any other orientation of the projector relative to the target, angle θ in Figure 6 equals the angle between projector bearing and target bearing.

The manner in which the three inputs of projector bearing, ship's heading, and target bearing are combined to locate the movable PS coil properly with respect to the fixed PS coils will be described with reference to Figure 7.

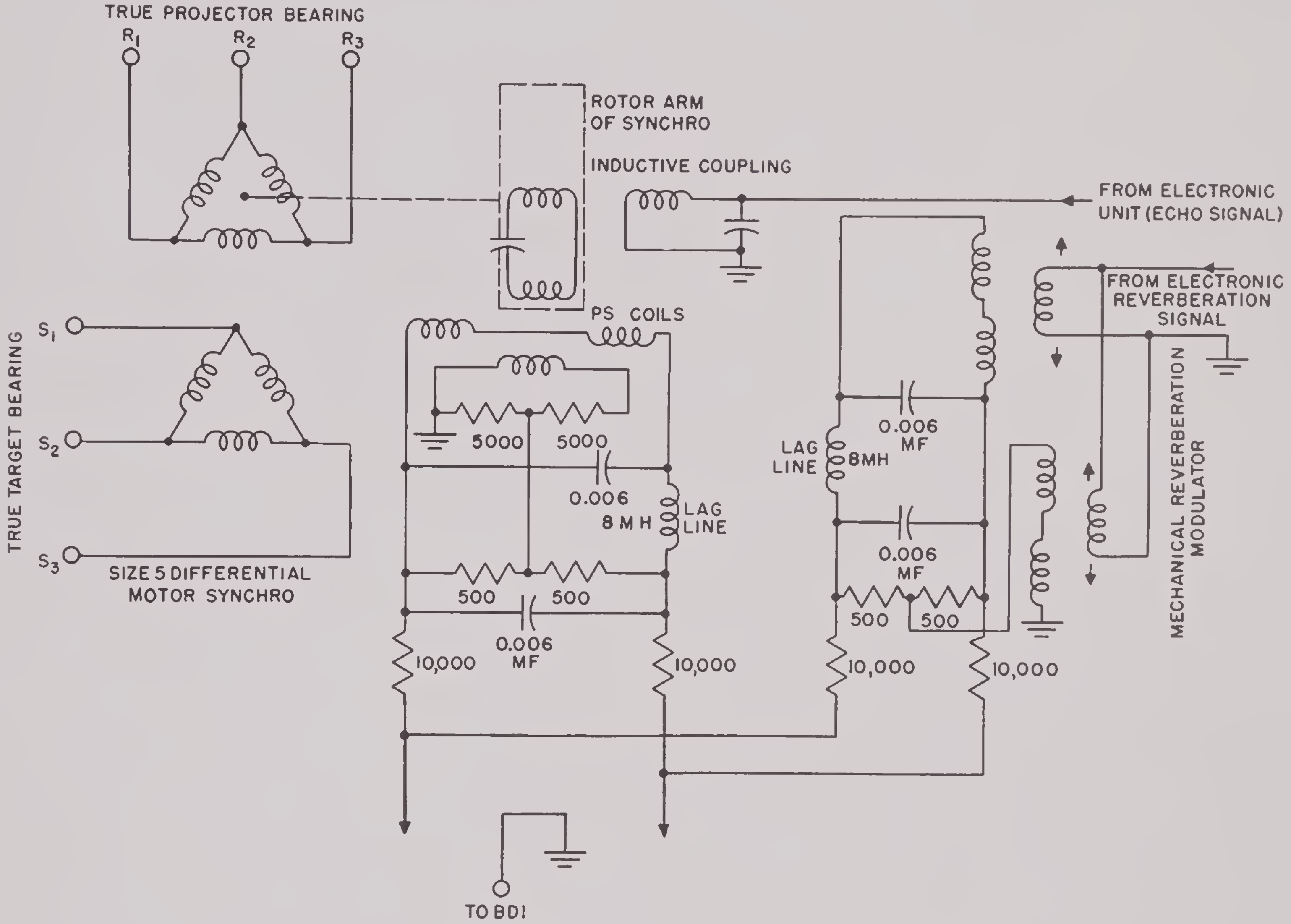

TRUE PROJECTOR BEARING
R_1
R_2
R_3
ROTOR ARM OF SYNCHRO
INDUCTIVE COUPLING
FROM ELECTRONIC UNIT (ECHO SIGNAL)
FROM ELECTRONIC REVERBERATION SIGNAL
PS COILS
TRUE TARGET BEARING
S_1
S_2
S_3
SIZE 5 DIFFERENTIAL MOTOR SYNCHRO
5000
5000
0.006
8 M H
LAG LINE
500
500
0.006 MF
10,000
10,000
LAG LINE
8MH
0.006 MF
0.006 MF
500
500
10,000
10,000
MECHANICAL REVERBERATION MODULATOR
TO BDI

FIGURE 3. Electrical schematic of OTE-4 mechanical unit.

As far as the attack teacher is concerned, these three quantities are independent of one another. The true bearing of ship's heading is obtained from the gyro repeater; the relative projector bearing is available in the form of a synchro signal generated by the rotation of the training wheel and bearing indicator; and the target's true bearing comes as a synchro signal from the optical follower in the attack teacher. Since all synchro-generators in the Sangamo QFA-3 device are operated with a 60:1 ratio, it is necessary to employ a synchro-normalizer unit to convert them to a 1:1 ratio. This conversion is indicated in the part of Figure 7 above the double-dashed line. Each of the three inputs actuates a synchro-motor that in turn drives a synchro-generator through a 60:1 gear train.

The normalized gyro signal (own-ship's true bearing) then feeds into the same synchro differential generator into which the normalized projector bearing signal is fed. The output of this differential generator, which is true projector bearing, then goes to the stator windings of the *differential motor* [DM] synchro shown at the bottom of Figure 7.

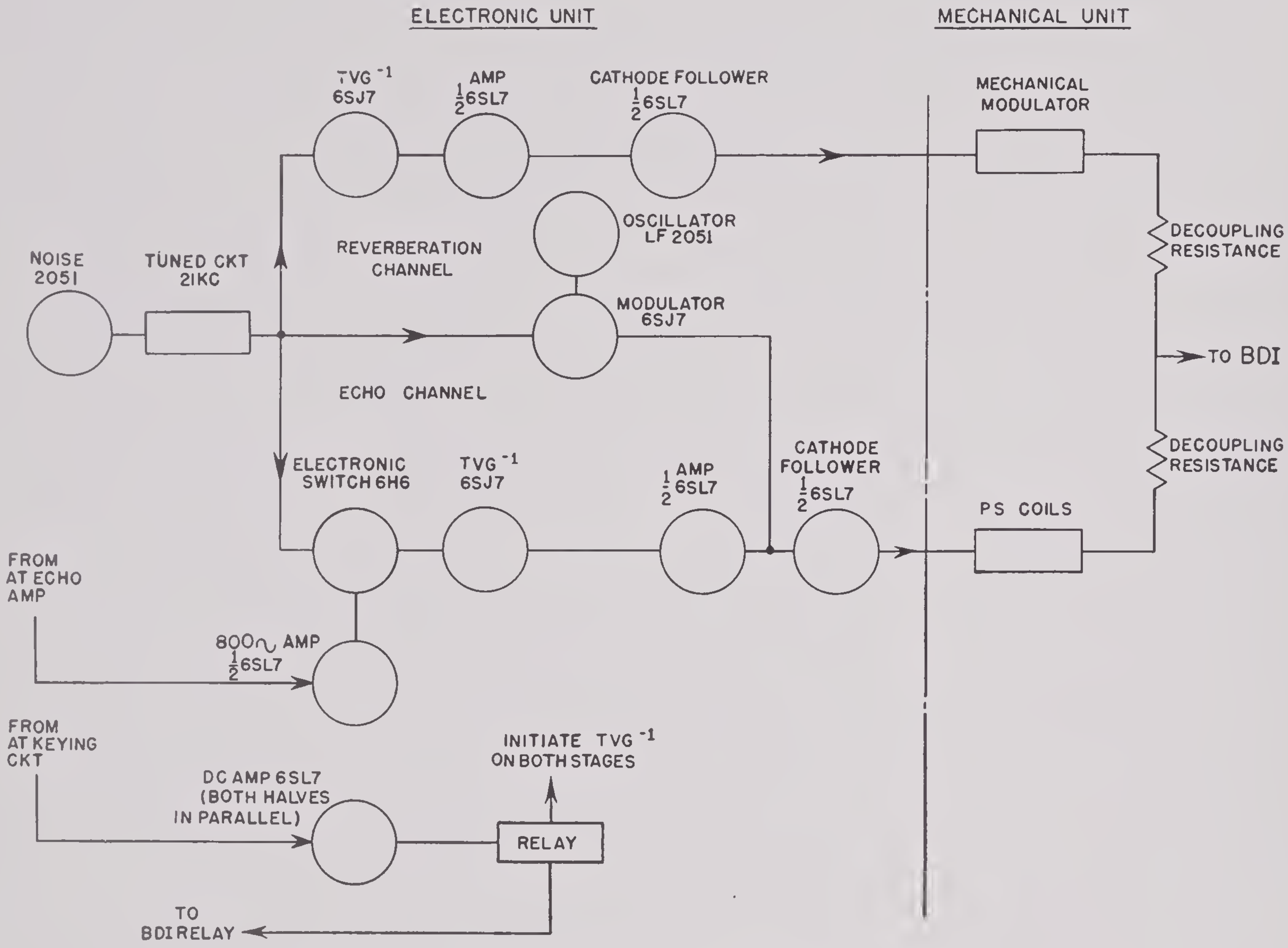

ELECTRONIC UNIT
MECHANICAL UNIT
TVG $^{-1}$ 6SJ7
AMP $\frac{1}{2}$6SL7
CATHODE FOLLOWER $\frac{1}{2}$6SL7
MECHANICAL MODULATOR
OSCILLATOR LF 2051
REVERBERATION CHANNEL
NOISE 2051
TUNED CKT 21KC
MODULATOR 6SJ7
DECOUPLING RESISTANCE
TO BDI
ECHO CHANNEL
DECOUPLING RESISTANCE
ELECTRONIC SWITCH 6H6
TVG $^{-1}$ 6SJ7
$\frac{1}{2}$ AMP 6SL7
CATHODE FOLLOWER $\frac{1}{2}$6SL7
PS COILS
FROM AT ECHO AMP
800∿ AMP $\frac{1}{2}$6SL7
FROM AT KEYING CKT
INITIATE TVG $^{-1}$ ON BOTH STAGES
DC AMP 6SL7 (BOTH HALVES IN PARALLEL)
RELAY
TO BDI RELAY

FIGURE 4. Functional diagram of OTE-4 electronic unit.

The normalized true target-bearing goes from its synchro generator to the rotor windings of the DM synchro shown at the bottom of Figure 7. Since, however, it is necessary to avoid any mechanical loading of the DM synchro-rotor, the connection cannot be made directly. Instead the signal is transferred by the use of inductive coupling to a coil mounted on the end of the rotor shaft and coaxial with it. The location of this coil is indicated in one of the labels on Figure 4. The DM synchro then assumes a position determined by the difference between the two true bearings, and rotates the arm carrying the movable or exciter PS coil so that the angle θ, shown at the bottom of Figure 7, is the angle of deviation of the projector from true target bearing. This motion of the exciter PS coil with respect to the fixed or pickup PS coils generates signals fed to the BDI unit. The trace produced in this manner on the BDI screen simulates accurately that encountered in actual service, even to the extent that no echo indication is obtained for angle θ greater than ±15°, a condition almost invariable in normal echo ranging.

REVERBERATION GENERATOR

The reverberation noise amplifier, which receives its signal from a 2051 gas tube, includes a 6SJ7 inverse *time-varied gain* [TVG] stage,

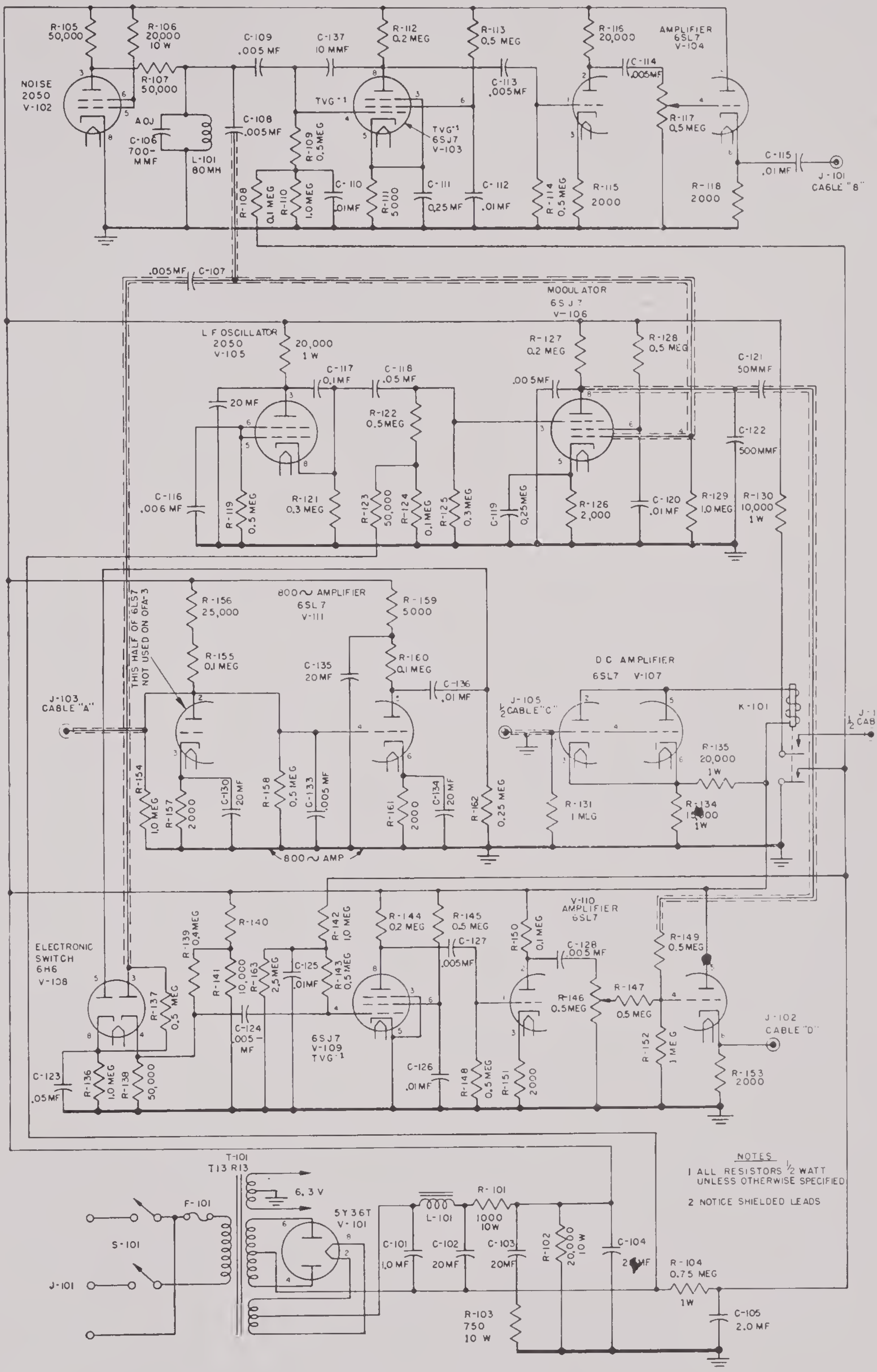

R-105 50,000
R-106 20,000 10 W
R-107 50,000
NOISE 2050 V-102
AOJ
C-106 700-MMF
L-101 80MH
C-109 .005 MF
C-137 10 MMF
C-108 .005MF
R-108 0.1 MEG
R-110 1.0MEG
R-109 0.5MEG
TVG-1
C-110 .01MF
R-111 5000
TVG-1 6SJ7 V-103
C-111 0.25MF
R-112 0.2 MEG
R-113 0.5 MEG
C-113 .005MF
C-112 .01MF
R-114 0.5 MEG
R-116 20,000
C-114 .005MF
AMPLIFIER 6SL7 V-104
R-117 0.5MEG
R-115 2000
R-118 2000
C-115 .01 MF
J-101 CABLE "B"
.005MF C-107
MODULATOR 6SJ7 V-106
L F OSCILLATOR 2050 V-105
20,000 1 W
C-117 0.1MF
C-118 .05 MF
20 MF
R-122 0.5MEG
R-127 0.2 MEG
R-128 0.5 MEG
.005MF
C-121 50MMF
C-122 500MMF
C-116 .006 MF
R-119 0.5 MEG
R-121 0.3 MEG
R-123 50,000
R-124 0.1MEG
R-125 0.3MEG
C-119 0.25MEG
R-126 2,000
C-120 .01MF
R-129 1.0MEG
R-130 10,000 1 W
THIS HALF OF 6SL7 NOT USED ON OFA-3
R-156 25,000
800∼ AMPLIFIER 6SL7 V-111
R-159 5000
R-155 0.1 MEG
C-135 20MF
R-160 0.1 MEG
C-136 .01 MF
J-103 CABLE "A"
J-105 ½ CABLE "C"
D C AMPLIFIER 6SL7 V-107
K-101
J-104 ½ CABLE C
R-135 20,000 1W
R-154 1.0 MEG
R-157 2000
C-130 20MF
R-158 0.5 MEG
C-133 .005 MF
R-161 2000
C-134 20MF
R-162 0.25 MEG
R-131 1 MEG
R-134 15,000 1W
800∼ AMP
ELECTRONIC SWITCH 6H6 V-108
R-139 0.4MEG
R-140
R-141 10,000
R-163 2.5MEG
C-125 .01MF
R-142 1.0 MEG
R-143 0.5MEG
R-144 0.2 MEG
R-145 0.5 MEG
C-127 .005MF
R-150 0.1 MEG
V-110 AMPLIFIER 6SL7
C-128 .005 MF
R-149 0.5MEG
R-137 0.5 MEG
C-124 .005 MF
6SJ7 V-109 TVG-1
R-146 0.5MEG
R-147 0.5 MEG
R-152 1 MEG
J-102 CABLE "D"
C-123 .05MF
R-136 1.0 MEG
R-138 50,000
C-126 .01MF
R-148 0.5 MEG
R-151 2000
R-153 2000
T-101 T13 R13
6.3 V
F-101
S-101
J-101
5Y3GT V-101
L-101
R-101 1000 10W
C-101 1.0 MF
C-102 20MF
C-103 20MF
R-102 20,000 10 W
C-104 20MF
R-104 0.75 MEG 1W
R-103 750 10 W
C-105 2.0 MF
NOTES
1 ALL RESISTORS ½ WATT UNLESS OTHERWISE SPECIFIED
2 NOTICE SHIELDED LEADS

FIGURE 5. Electrical schematic of OTE-4 electronic unit.

a cascade-triode amplifier stage, and a cathode-follower output stage. The last two stages use the two triodes of a 6SL7 tube. From the cathode follower the signal goes to a mechanical reverberation unit. This unit consists of a motor-driven, irregularly notched rotary cam, which varies the coupling between two sets of PS coils. The coils and cam are shown in Figure 2. The cam causes the two arms on which the transmitter coils are mounted to oscillate so that each transmitter coil moves in irregular fashion below its own pair of pickup coils. The two pickup coils in each set are wired in phase opposition; the wiring is shown at the right-hand side of Figure 3.

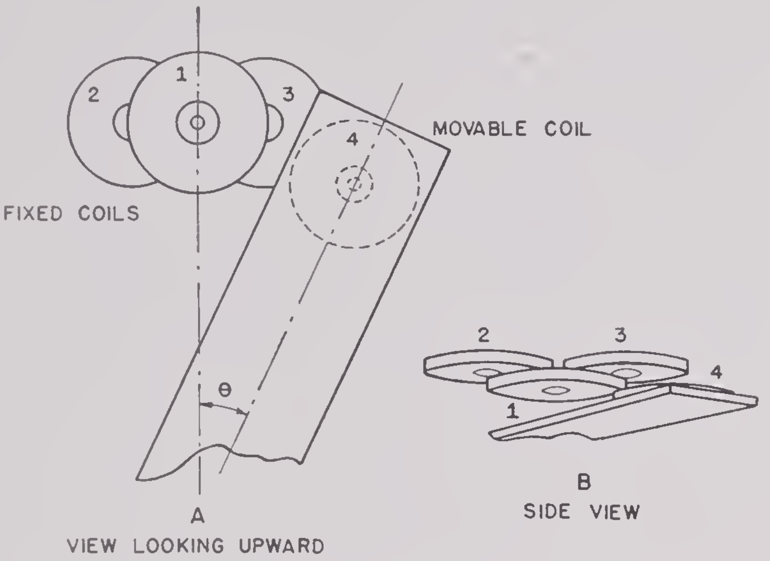


Figure 6. Arrangement of projector simulator coils in OTE-4.

The magnitude and phase of the voltage output of each set of pickup coils at any instant depend upon the momentary position of the transmitter coils. The output of one set is passed through a 90-degree phase-shifting network. One half of it is then combined in one direction with the output of the other coils to produce the reverberation input to a BDI channel, whereas the other half is combined in the opposite direction to produce the reverberation input for the other BDI channel. This results in irregular phase variation of the input signal, which is already varying in amplitude because of the second set of coils. Thus, the output of the unit is two-channeled and of irregular relative phase and amplitude, simulating the output of a split projector when excited by actual reverberation.

ECHO GENERATION

The echo generator, which feeds a 6H6 electronic keying stage, also receives its excitation from the 2051 noise tube. One half of the 6H6 stage acts as an electronic switch, whereas the other half is used as a half-wave rectifier to obtain a d-c keying pulse from the 800-c echo pulse produced by the attack teacher. The 6H6 stage is followed by a 6SJ7 stage arranged to give inverse TVG amplification. The resultant 20-kc pulse goes to a 6SL7 tube, the first half of which is used as a cascade amplifier and the second half as a cathode follower to feed the PS coils. Again a two-channeled output is obtained. This is mixed with the reverberation signals by resistance-bridging networks, and passed on to the BDI input circuits.

SYNCHRONIZATION CIRCUITS

Reverberation initiation of the OTE-4 unit has to be synchronized with that of the attack teacher and an echo indication must be produced at the proper time to correspond to the audible echo generated by the attack teacher. The OTE-4 is connected to the attack teacher at the *N* plug on the sonar stack and obtains its keying pulse for the ping (which initiates inverse TVG) from the attack teacher's keying circuits. The keying signal is a ±145-volt pulse applied to the grid of a 6SL7 with both triodes in parallel. The triodes actuate a relay with two normally open contacts, one of which momentarily shorts the inverse TVG capacitor while the other applies about 60 volts to the BDI relay coils. The echo in the attack teacher occurs as a short pulse of an 800-c signal picked up photoelectrically from a modulated light source. This signal is available on the plug *N* on the sonar stack and is of the order of 1 volt for a reasonably loud echo. The 800-c echo signal passes through an amplifier consisting of one half of a 6SL7 tube. The output of the 6SL7 is coupled to one half of a 6H6 to give half-wave rectification. The rectified output passes through a simple RC filter that yields a positive d-c pulse of about 5 volts; this voltage is sufficient to key the echo amplifier by neutralizing the fixed bias on the other half of the 6H6, which is used as an electronic switch.

Propeller-Noise Generation

A 6SJ7 noise amplifier is suppressor-grid modulated by the output of a 5- to 7-c oscillator. This low frequency corresponds to the propeller throbs of a slow-speed submarine, and the resultant modulated noise closely simulates propeller noise as heard when using listening gear. The modulated noise is fed to the grid of the cathode-follower output tube of the echo amplifier, and thence to the BDI through the PS coils. This gives the propeller noise, like the echo, a directional characteristic, making it appear on the BDI screen in a manner similar to that observed in practice. Moreover, the propeller noise, as in actual operation, is of rather low intensity as compared to the echo, and the BDI gain has to be increased to observe it.

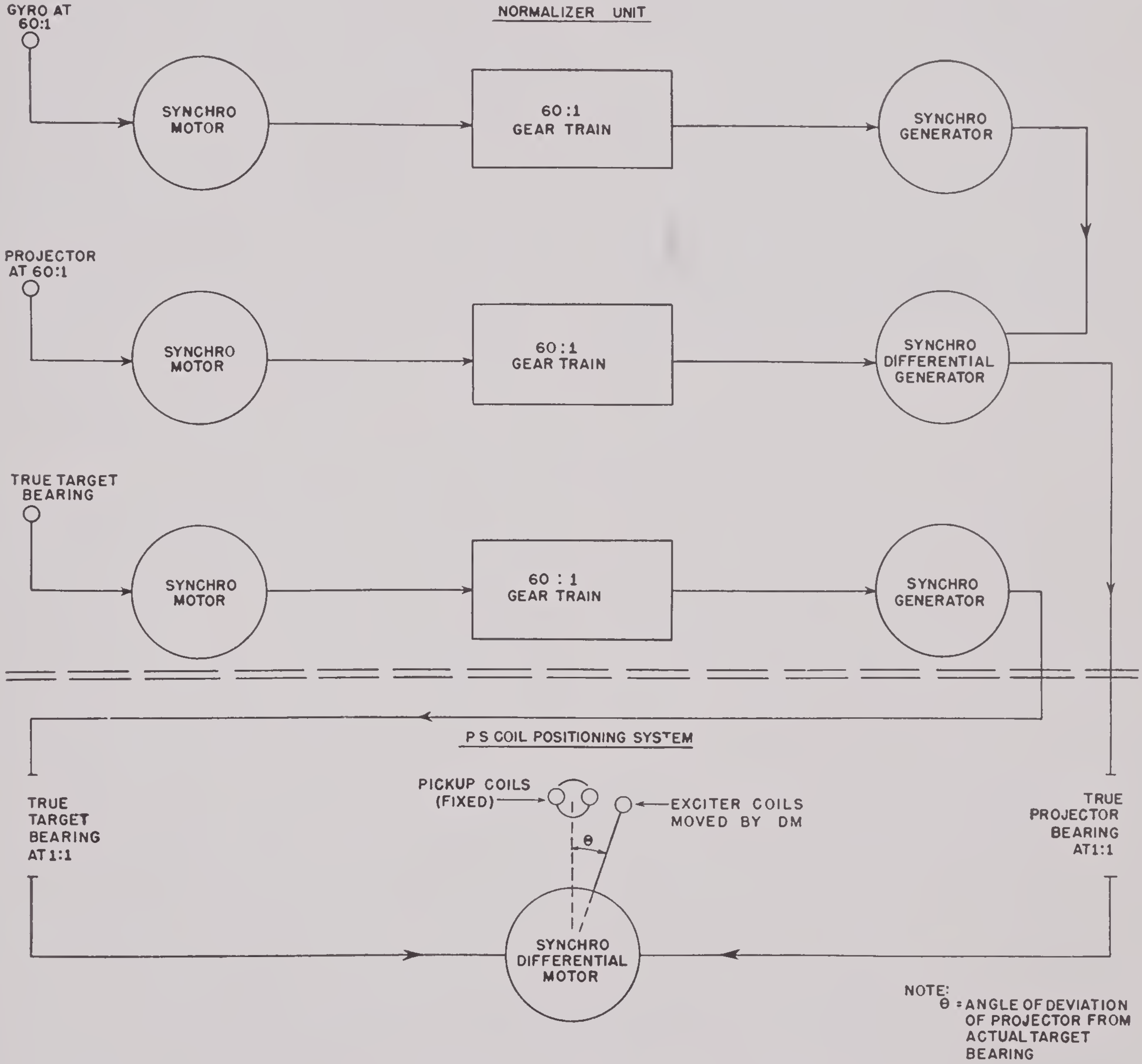

GYRO AT 60:1
NORMALIZER UNIT
SYNCHRO MOTOR
60:1 GEAR TRAIN
SYNCHRO GENERATOR
PROJECTOR AT 60:1
SYNCHRO MOTOR
60:1 GEAR TRAIN
SYNCHRO DIFFERENTIAL GENERATOR
TRUE TARGET BEARING
SYNCHRO MOTOR
60 : 1 GEAR TRAIN
SYNCHRO GENERATOR
P S COIL POSITIONING SYSTEM
TRUE TARGET BEARING AT 1:1
PICKUP COILS (FIXED)
EXCITER COILS MOVED BY DM
θ
TRUE PROJECTOR BEARING AT 1:1
SYNCHRO DIFFERENTIAL MOTOR
NOTE:
θ = ANGLE OF DEVIATION OF PROJECTOR FROM ACTUAL TARGET BEARING

Figure 7. Functional diagram of OTE-4 synchro and PS coil systems.

8.3 CONCLUSION

The three units of OTE-4 which were constructed fulfilled their interim function satisfactorily. Since the bearing deviation indicator was later included as a basic element in attack teacher equipment, no further work in this direction is recommended.

Assisting Ship Projector

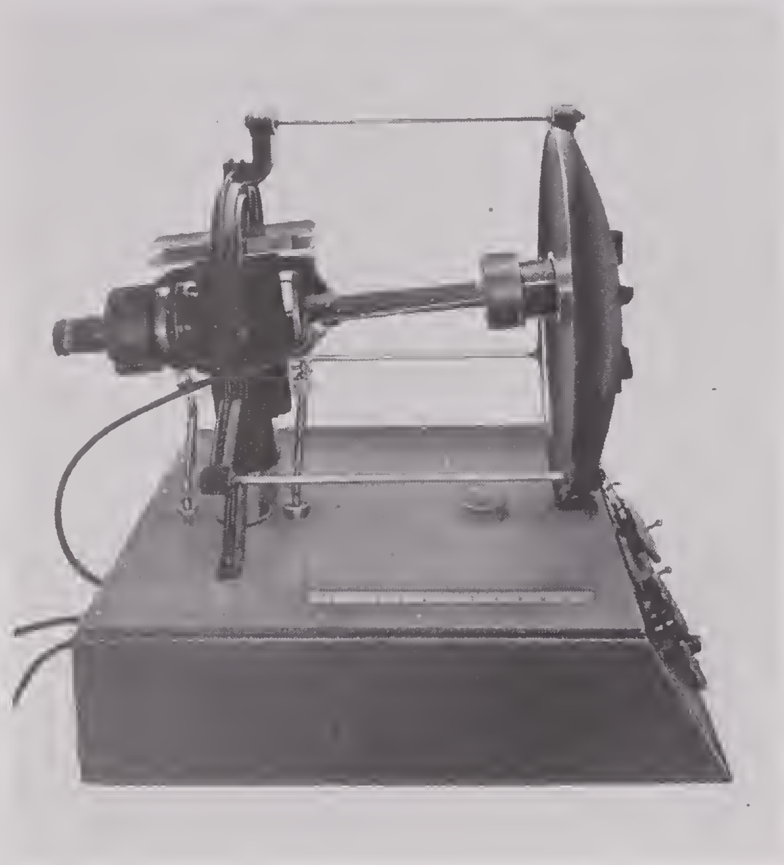


FIGURE 8. Assisting ship projector.

The assisting ship projector [ASP], developed by UCDWR, is designed for use in conjunction with a standard attack teacher to permit simulation of a two-ship attack. The essential components of the ASP are an optical projector for forming images and a control box upon which the projector assembly is mounted. The instrument projects a light spot with the outline of a ship onto the attack teacher screen and, by means of an electro-mechanical system with appropriate controls, moves the spot across the screen with any desired course and speed. A graduated measuring line, centered on the ASP ship's image and adjustable in azimuth, is projected onto the screen for the purpose of reading ranges. Bearings between the two surface ships may be read from a control box dial or a remote bearing repeater. The device can be used as part of any system in which a mechanical problem generator with projector is needed.

8.4 INTRODUCTION

In an antisubmarine attack in which two surface ships take part, it is current practice for one ship only (the directing ship) to echo-range on the target, while the attacking ship, with sonar gear secured, is conned by voice-radio from the directing ship into the proper position to drop depth charges. This procedure requires, on the directing ship's *dead reckoning tracer* [DRT], a simultaneous plot of the submarine (from sonar ranges and bearings), of the attacking ship (from radar ranges and bearings), and of the course of the directing ship herself. Using information obtained from this plot, the conning officer of the directing ship sends the attacking ship orders controlling her course, speed, and time to drop depth charges.

In the training course at the West Coast Sound School [WCSS], two attack teachers projecting images on the same screen were first used to simulate a two-ship attack. This makeshift arrangement had the disadvantage of tying up two attack teachers, thereby cutting in half the number of teams which could be trained at one time. Moreover, there was no method by which doppler could be introduced into the echoes. There was also no way of obtaining BDI bearings on the target. This lack necessitated computing center bearings from cut-ons, only center bearings being useful to the plotters. Finally, ranges of the attacking ship had to be measured manually.

The assisting ship projector is designed to overcome all of these drawbacks. It projects on the screen an image representing the attacking ship. Only one attack teacher is needed, which simulates the echo-ranging (directing) ship and submarine in the orthodox manner. Doppler and BDI bearings can be obtained. The ASP is equipped with an optical measuring line centered on the attacking vessel, adjustable in azimuth and projected on to the screen. From this line ranges can be read directly. Bearings are indicated on a dial on the control box and, through a selsyn, on a remote bearing repeater.

8.5 DESCRIPTION

The equipment consists of an optical projector for forming the images and a control box upon which the projector assembly is mounted (see Figure 8). The mechanism which controls the course and speed of the ship's image and the orientation of the range-line image is housed inside the control box.

The projector, the parts of which are shown in Figure 9, contains a lens-tube assembly with ship and range-line reticles in reticle cages which rotate in bearings; a lamp house for the projector lamp and condenser lenses, with brackets bolted to its front and back for holding the gears through which the reticle cages and the drive wheel are rotated; a tail-spindle assembly housing a rotating shaft which controls the course of the drive wheel; a motor and drive wheel assembly; and gimbal frames and bowl. The gimbals, which are pivoted to the lamp house, hold the projector assembly, and the bowl, secured to the outer gimbal frame by means of three rods, is so placed that the drive wheel travels over its concave spherical surface. When this takes place, the projector swings in the gimbals, moving the images across the screen.

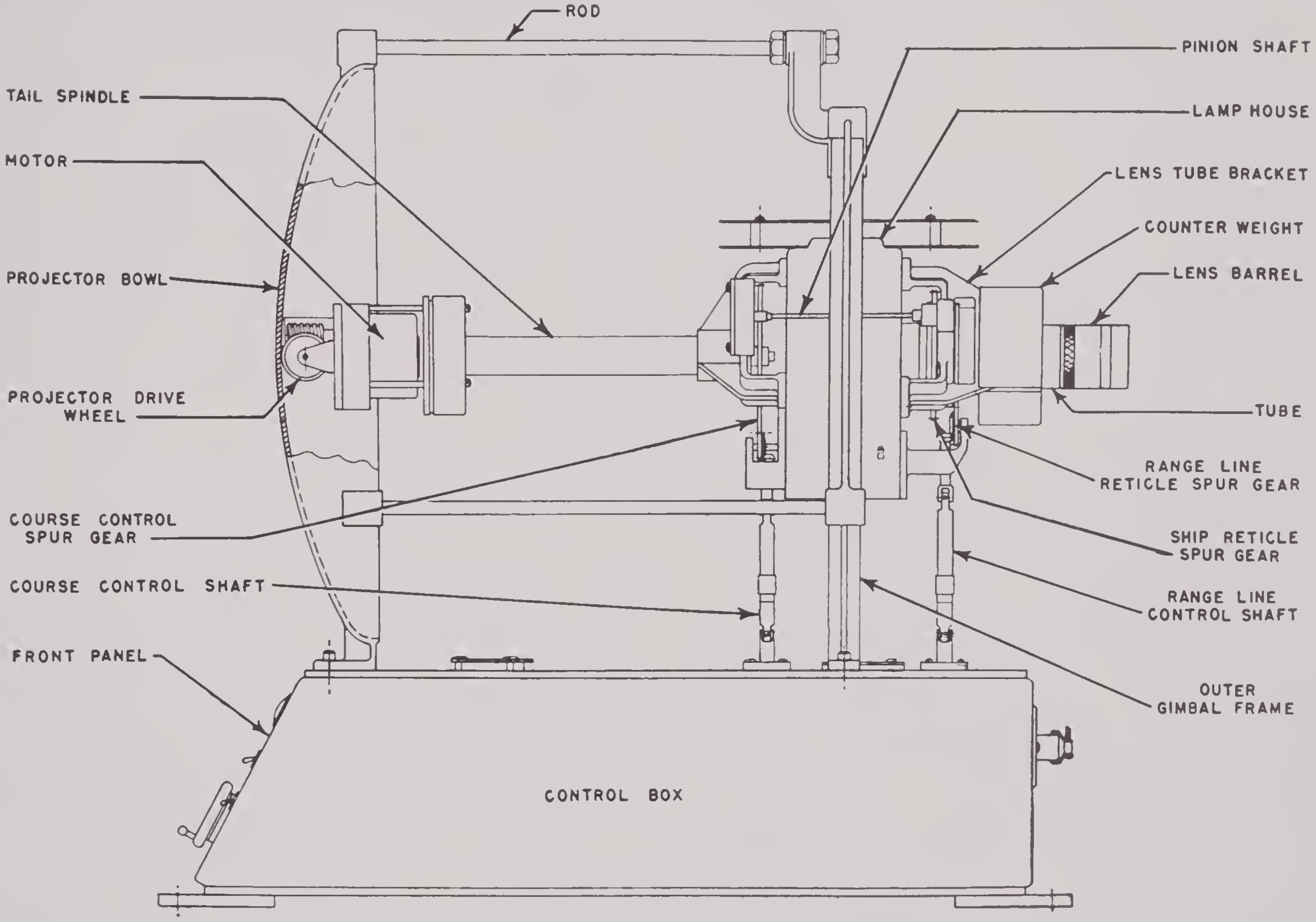

ROD
PINION SHAFT
TAIL SPINDLE
LAMP HOUSE
MOTOR
LENS TUBE BRACKET
COUNTER WEIGHT
PROJECTOR BOWL
LENS BARREL
PROJECTOR DRIVE WHEEL
TUBE
RANGE LINE RETICLE SPUR GEAR
COURSE CONTROL SPUR GEAR
SHIP RETICLE SPUR GEAR
COURSE CONTROL SHAFT
RANGE LINE CONTROL SHAFT
FRONT PANEL
OUTER GIMBAL FRAME
CONTROL BOX

FIGURE 9. Diagram of projector in cross section.

On the front panel of the control box which forms the base for the projector assembly are three cranks and a knob (for range-line, speed, rudder, and initial-course control), and on a subpanel are four corresponding indicating dials, seen through windows in front panel. The operation of these four controls is shown diagrammatically in Figure 10 and described below.

Azimuth Control for the Range Line. Through a train of gears the range crank turns a shaft attached by a universal joint to the gear assembly mounted on the front of the lamp house. This gear assembly in turn engages the spur gear on the range-line reticle cage, so that the range line is rotated about the ship's image. At the same time the azimuth dial indicates the position of the range line, which is graduated from 0 to 4,000 yd.

Speed Control. The speed knob, which is geared to an indicator graduated in knots from 0 to 35, regulates through a system of shafts and gears the output speed of the disk transmission mounted on the base plate (see Figure 10). The operation of the speed-control mechanism moves the image on a straight course only. Changes in course are governed by the rudder control.

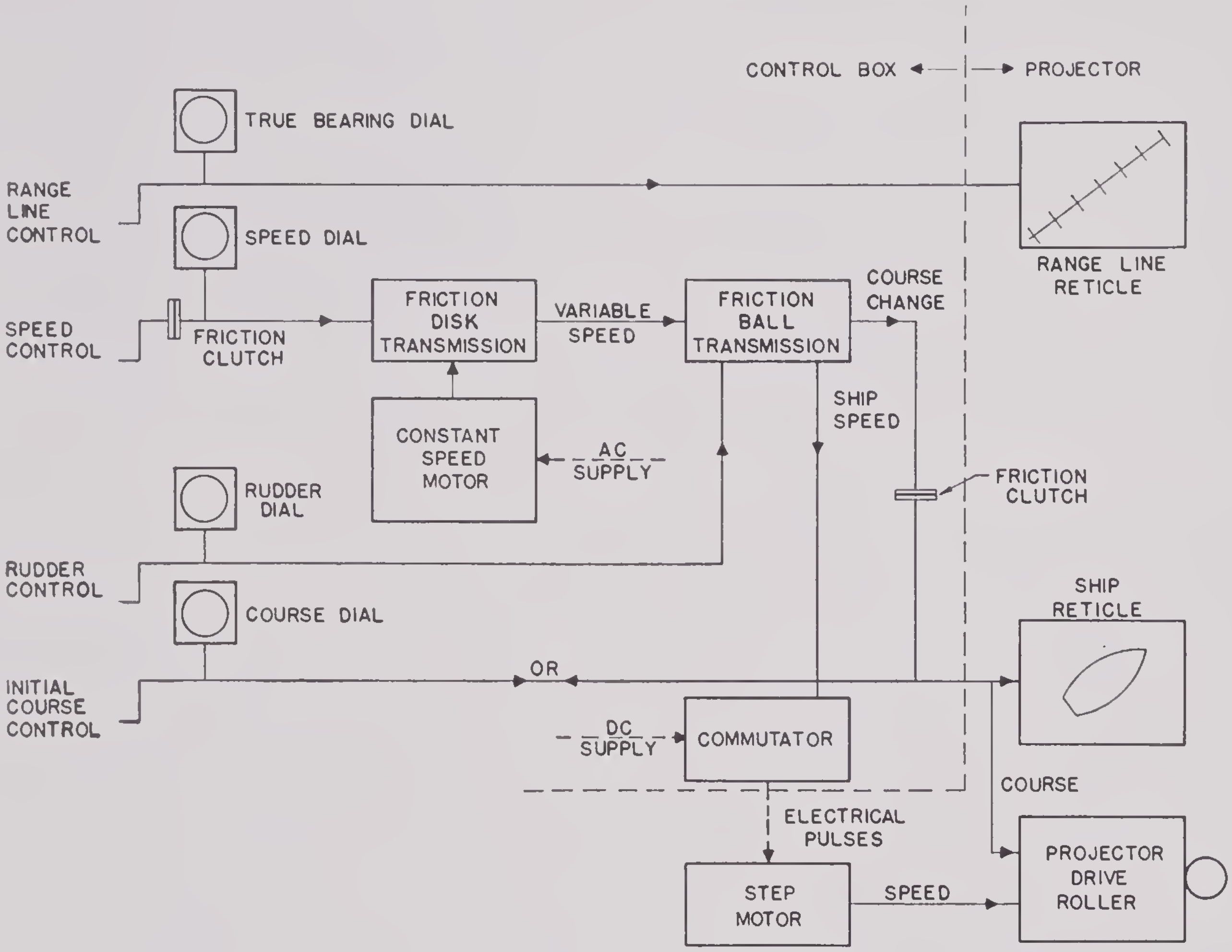

CONTROL BOX
PROJECTOR
TRUE BEARING DIAL
RANGE LINE CONTROL
SPEED DIAL
RANGE LINE RETICLE
SPEED CONTROL
FRICTION CLUTCH
FRICTION DISK TRANSMISSION
VARIABLE SPEED
FRICTION BALL TRANSMISSION
COURSE CHANGE
CONSTANT SPEED MOTOR
AC SUPPLY
SHIP SPEED
FRICTION CLUTCH
RUDDER DIAL
RUDDER CONTROL
COURSE DIAL
SHIP RETICLE
INITIAL COURSE CONTROL
OR
DC SUPPLY
COMMUTATOR
COURSE
ELECTRICAL PULSES
STEP MOTOR
SPEED
PROJECTOR DRIVE ROLLER

FIGURE 10. Block diagram of assisting ship projector.

Rudder Control. When the rudder is applied by turning the rudder crank, the rudder indicator to which the crank is geared will show the number of degrees of rudder applied. Two functions are accomplished by the rudder crank: (1) The ship's speed is reduced in simulation of the loss of headway of a vessel in a turn; and (2) the course-change roller is set in motion.

Initial-Course Control. In setting up a new problem, the ship's initial course can be set by means of the initial-course knob. This knob, by means of a shaft in the course-change mechanism, alters the course of the drive wheel and swings the ship's reticle to the desired heading. In order to maintain a steady course when desired, without constant minor adjustments of the rudder crank to control yawing, an automatic antiyaw device is installed.

8.6 INTRODUCTION

Depth charge driller installations include an arrangement of K guns and depth charge racks that are intended to simulate actual ship conditions as closely as possible. They are used to train newly organized groups of men who are later to act together as crews and to provide refresher courses for experienced men.

When a depth charge pattern recorder is associated with this equipment, the firing of a K gun or the release of a depth charge in a practice drill permits an electric current to pass through one of eight solenoids in the pattern recorder. This activates the needle or electric punch within the solenoid, forcing it upward to punch a hole in the paper strip moving above it. The electric punch is then released and drops back to its original position. The punched paper strip thus charts the simulated depth charge explosions and measures the ability of the crew to obtain a predetermined depth charge pattern.

By adjusting the position of the eight electric punch assemblies and the speed at which the paper strip travels, it is possible to simulate any arrangement of K guns and depth charge racks on an antisubmarine [A/S] vessel traveling at any speed.

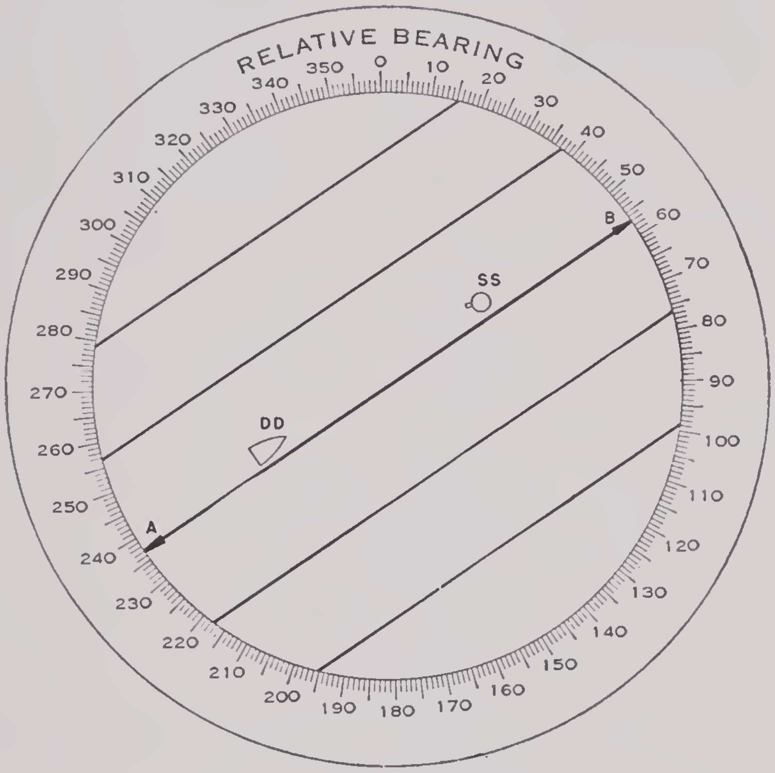


FIGURE 11. Attack teacher azimuth grid.

Attack Teacher Azimuth Grid

The attack teacher azimuth, developed by UCDWR, is a means of projecting on the instructor's screen of an attack teacher a system of rotatable parallel lines within a fixed circular azimuth scale, as shown in Figure 11. By orienting the lines so that they are parallel to an imaginary line joining the destroyer and submarine images and then taking the reading on the azimuth scale opposite the central line, the instructor can ascertain the true bearing of the submarine target and thus check the true bearings reported to the conning officer by the sonar operator.

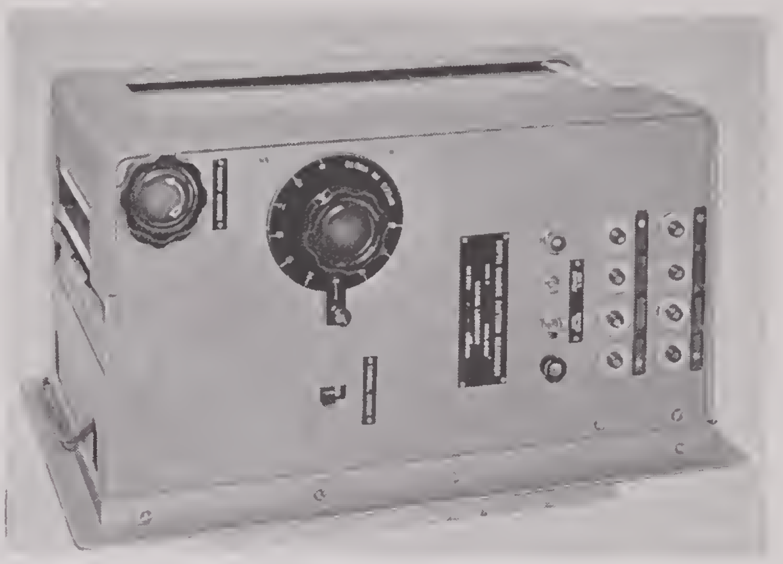


FIGURE 12. Depth charge pattern recorder.

Depth Charge Pattern Recorder

The depth charge pattern recorder, developed by UCDWR, is a device for recording the simulation of the depth charge pattern thrown in shore-based attack teacher exercises. In these exercises, the simulated depth charges are laid to execute a desired pattern. The recorder supplies a scale record of this pattern by associating with the depth charge driller a number of appropriately actuated needles which punch holes in a moving strip of paper. The points at which the depth charges explode in relation to the path of the attacking vessel can then be deduced.

8.7 GENERAL DESCRIPTION

The depth charge pattern recorder, enclosed in a steel case, weighs 84 lb. Figure 12 gives a general view of the unit with its control panel.

ELECTRIC PUNCHES

In the upper part of the recorder, directly under a grille across which the recording paper travels, is an assembly of eight solenoid-actuated electric punches or marker needles. This assembly, removed from the case, is shown in Figure 13. The electric punches are movable, so that all eight or any combination of them may be used. They may be screw-clamped to any of five support bars to conform to the positions of K guns or depth charge racks on the A/S vessel. The five support bars (or as many of them as are used at one time) are held on two bars with beveled edges. When four screws are removed, it is possible to rotate the beveled-edge bars and the support bars through 90 degrees, according to requirements for special patterns. All seven bars are marked with a scale arbitrarily set, so that 1/6 in. equals 5 yd.

Since a rigid needle might be bent by the drag of the moving paper or the paper would be torn rather than punched, each marker needle is connected to its solenoid plunger by a hinge which enables the needle to free itself as the paper travels on (see Figure 14). Extra clamping nuts and screws and small extension arms are provided to make possible slight adjustments in the positions of the needle points.

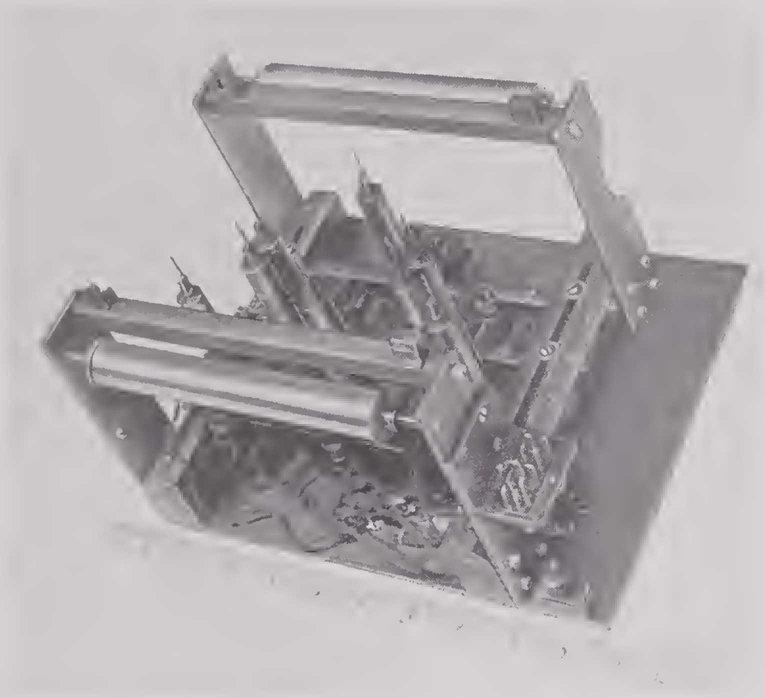


FIGURE 13. Electric punch assembly.

SOLENOID CIRCUITS

The recorder operates on 100 to 120-volt 60-c alternating current. From the secondary of a transformer which steps the voltage down to 41 v, eight circuits lead in parallel to the eight solenoid coils (see Figure 15). Via terminals 5 to 20, each of these circuits passes through a switch in the appropriate K gun or depth charge rack in the depth charge driller. When the power supply is on and one of these switches is closed, the appropriate solenoid coil actuates its marker needle. In addition, eight push buttons on the front panel of the recorder parallel terminals 5 to 20, thus providing a means of actuating the solenoid needle separately for test or demonstration purposes, or in the event that one needle is used independently to mark the time when the conning officer gives the order to fire.

SERIES RELAY AND THERMAL CUTOUT SWITCH

A series relay and a thermal cutout switch are provided to protect the solenoid coils from heat damage in case the contacts on the depth charge racks or K guns remain closed too long.

When an electric punch is actuated, the relay armature closes a circuit through the relay contacts, the heat element, and the resistor R-1 (see Figure 15). If this current continues to flow for about 15 seconds, endangering the solenoid coils, a thermo-sensitive alloy in the heating element will soften and release blades B-1 and B-2 in the thermal cutout, thus interrupting the power supply to all solenoid coils. Resistor R-1, by limiting the current through the heat element, determines the length of time

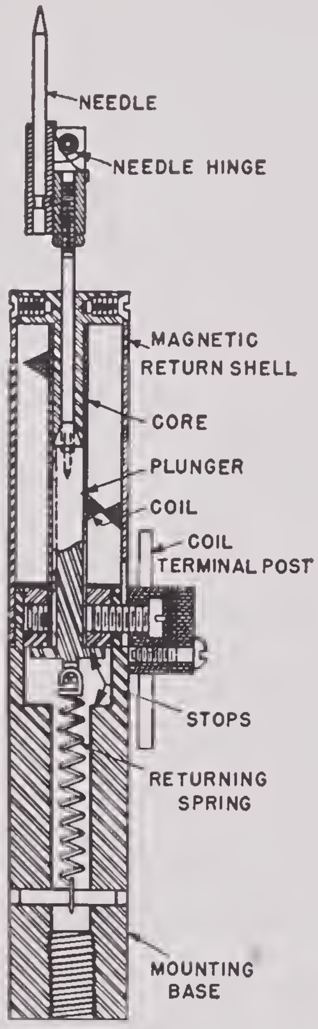


FIGURE 14. Construction drawing of electric punch.

that the current may flow before the alloy becomes soft.

During the running of a pattern, each depth charge switch is generally closed for only a fraction of a second and the whole pattern can be run within the 15-second period. If, however, this period has been exceeded and the thermal cutout has been tripped as a result of the alloy softening, it is necessary to wait for the alloy to cool and then reset the cutout by flipping the cutout switch on the front panel. The series relay is incorporated in the circuit so that the 15-second limit applies whether one or all eight of the solenoids are energized.

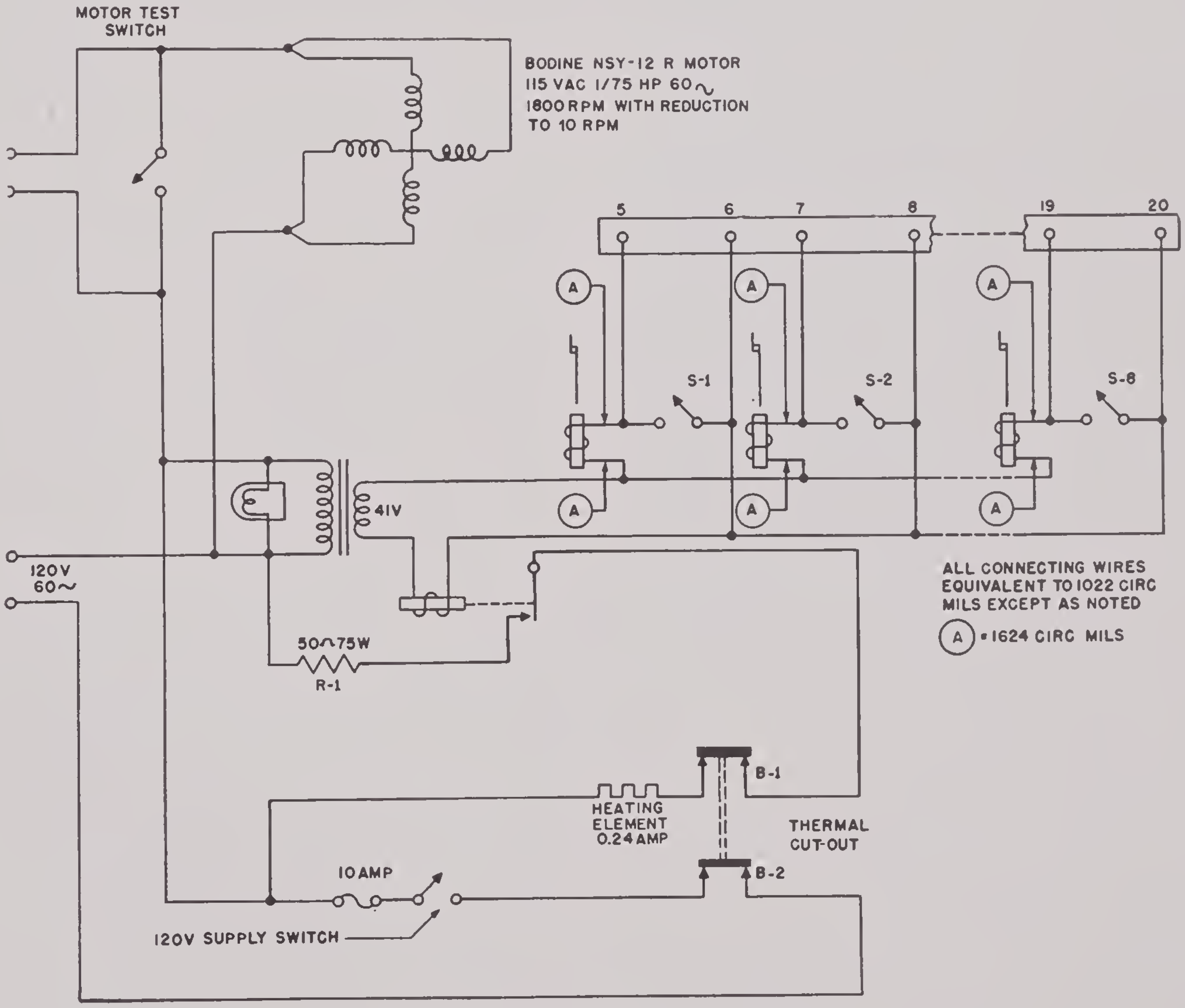
Marking Paper Assembly

A paper support bar mounted between two brackets is designed to hold the roll of paper, which is fed over two small rollers above the electric punch assembly, then down the side of the recorder in front of a bakelite platen, next halfway around a sprocket roller, and finally through a paper chute into a basket. While the paper is passing over the electric punches, it moves under a grille which, when a needle is actuated, holds the paper taut and prevents the needle from pushing it away instead of puncturing it.

A Bodine fractional horsepower motor drives the sprocket roller which pulls the paper. The speed of this motor may be controlled to correspond to any speed of the hypothetical A/S vessel.

8.8 CONCLUSION

The thirty units of the depth charge pattern recorder which were built were widely distributed in Navy schools and served as a valuable adjunct to the depth charge driller.


MOTOR TEST SWITCH
BODINE NSY-12 R MOTOR
115 VAC 1/75 HP 60~
1800 RPM WITH REDUCTION TO 10 RPM
5
6
7
8
19
20
A
S-1
S-2
S-8
41V
120V 60~
50Ω 75W
R-1
B-1
HEATING ELEMENT 0.24 AMP
THERMAL CUT-OUT
10 AMP
B-2
120V SUPPLY SWITCH

ALL CONNECTING WIRES EQUIVALENT TO 1022 CIRC MILS EXCEPT AS NOTED

Ⓐ = 1624 CIRC MILS

FIGURE 15. Partial electric schematic for depth charge pattern recorder.

Chapter 9

SHIPBOARD TRAINERS FOR SOUND OPERATORS AND ATTACK TEAMS

SINCE SONAR operators and officers may contact enemy submarines only rarely after going to sea, shipboard drills to keep their skills from becoming rusty are essential. Synthetic methods developed to simulate echoes and attacks at sea are the *echo injector* and the *shipboard antisubmarine attack teacher* [SASAT], Models A and B, described in this chapter. Adjuncts to these devices, likewise covered here, are the WEA-1 and WEA-2 adapters for SASAT-A, the SASAT *slide rule*, and the *practice attack meter.*

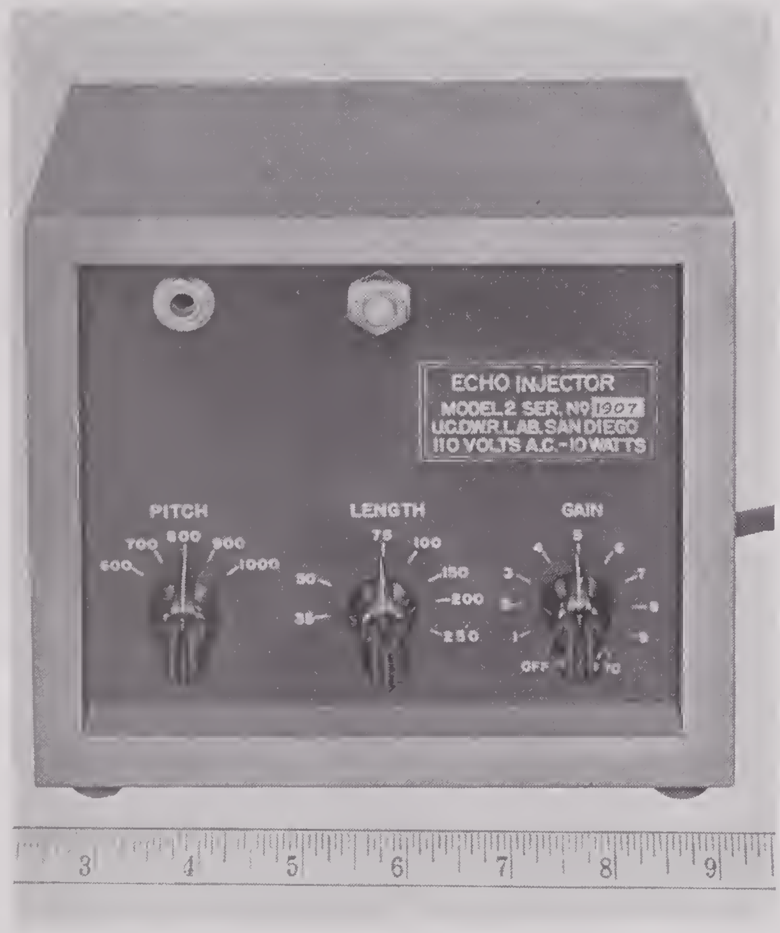


FIGURE 1. Echo injector.

Echo Injector

The echo injector, developed by UCDWR, is a simple electronic device which, when connected to the speaker in the sonar stack, can be used to produce fictitious echoes without interfering with the normal operation of the sonar equipment. Four controls on the front of the panel provide means for adjusting output frequencies from 600 to 1,000 c, for controlling the duration of the echo tone over the range of 35 to 250 yd in water, for adjusting the intensity of the output signal, and for opening the power switch. A pushbutton at the top of the panel is used by the instructor to initiate the echo a suitable time interval after the ping has been transmitted. The use of the echo injector is limited to checking the alertness of the sound operator on watch at the sonar stack speaker, since the device does not provide exact range, doppler, or bearing information.

The echo injector Model 2 is shown in Figure 1. Of the four controls provided on the front panel, the knob marked *"pitch"* adjusts output frequencies from 600 to 1,000 c, with the highest accuracy at 800 c. The knob marked *"length"* controls the duration of the echo tone over the range of 35 to 250 yd (in water). The knob marked *"gain"* adjusts the intensity of the output signal and, at the minimum intensity position, opens the power switch. A pushbutton at the top center of the panel is used for manually initiating the echo note.

With the gain control set at a low value and with the pitch and length controls set at the desired levels, the instructor must listen to the pings of the sonar gear and press the pushbutton at the instant a real echo would be received if an actual contact had been made. When the controls are properly adjusted, one short echo tone results each time the pushbutton is pressed. A delay system provides that the button must be left in its released position from one-half to a full second before another echo can be produced. The instructor may monitor the echo tone before transmitting it to the sonar speaker by plugging a pair of headphones into the panel in place of the output cord.

CIRCUIT DESIGN

The electric circuit for the echo injector is shown in Figure 2. Tube V-101 is a triode operating as a positive-bias multivibrator, the frequency of which increases as the bias voltage applied to the grids is increased. The relative values of plate load resistance and cathode bias resistance are so chosen as to provide a substantially linear frequency response with respect to grid bias voltage in the upper part of the operable frequency range of the multivibrator; values of feedback capacity (0.0016 μf) and grid leak (1 megacycle) are so chosen as to keep the nonlinear frequency range below the range required of the echo injector. The expected variation in characteristics of the 12SL7 vacuum tube used here will not upset this linearity of the frequency response but will affect the frequency sensitivity, that is, the number of cycles per second that the frequency changes for a given change in grid bias voltage. This expected variation in frequency sensitivity between different tubes is compensated by an alignment control which consists of a 15,000-ohm rheostat connected in series with a 100,000-ohm potentiometer that constitutes the grid bias potentiometer. This alignment rheostat changes the current through the pitch control potentiometer and therefore the voltage drop across it and so permits an adjustment of the number of volts change of grid bias obtained by a given rotation of the pitch control knob.

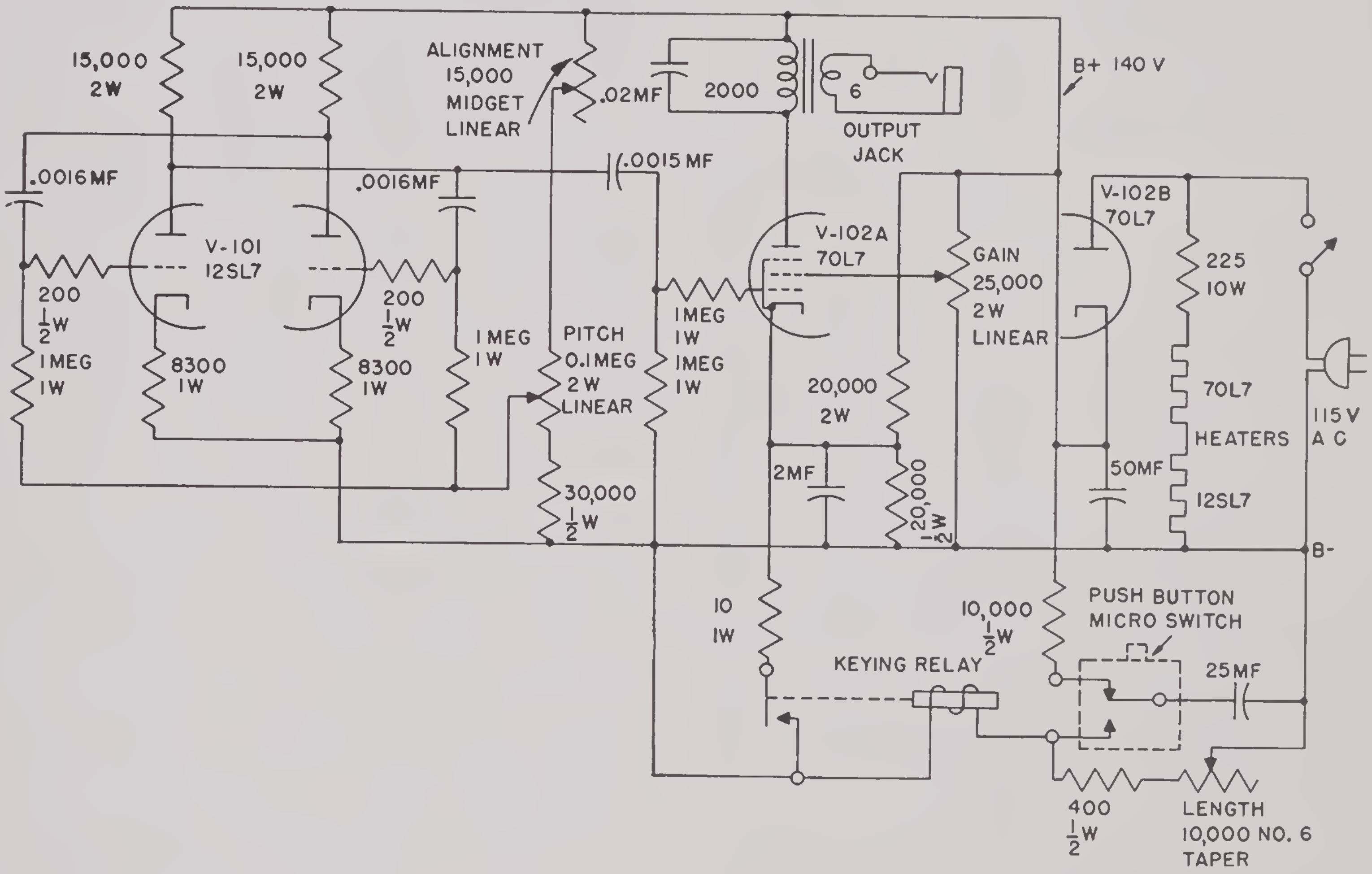

15,000
2W
15,000
2W
ALIGNMENT
15,000
MIDGET
LINEAR
.02MF
2000
6
OUTPUT
JACK
B+ 140 V
.0016MF
.0016MF
.0015 MF
V-101
12SL7
200
½W
200
½W
1MEG
1W
8300
1W
8300
1W
1MEG
1W
PITCH
0.1MEG
2W
LINEAR
1MEG
1W
1MEG
1W
V-102A
70L7
GAIN
25,000
2W
LINEAR
V-102B
70L7
225
10W
70L7
HEATERS
12SL7
115 V
A C
20,000
2W
2MF
20,000
½W
50MF
30,000
½W
B-
10
1W
10,000
½W
KEYING RELAY
PUSH BUTTON
MICRO SWITCH
25MF
400
½W
LENGTH
10,000 NO. 6
TAPER

FIGURE 2. Electric schematic for the echo injector.

The multivibrator drives an output stage which uses the beam power section V-102A of V-102. A 1-megohm resistor in series with the control grid of this power tube prevents the output stage from imposing enough load on the multivibrator to affect the frequency. Normally, the output stage is biased below cutoff because the cathode is held at approximately 70 volts positive by a voltage divider circuit consisting of two 20K resistors. For transmitting an echo tone, the lower one of these resistors is short-circuited by means of a keying relay, thereby bringing the cathode to zero potential (with respect to the B supply). A 2-μf condenser is placed in shunt with this resistor to eliminate the "pop" that would otherwise occur at the end of the echo tone. A 10-ohm resistor in series with the relay contacts prevents the discharge from the condenser from injuring the contacts.

The gain, or output intensity, is controlled by the screen voltage of the output stage. The output transformer has an impedance ratio of 2,000:6 to match a 6-ohm load and delivers a maximum output of 2 watts. A 0.02-μf condenser across the primary of the output transformer rounds off the square wave from the multivibrator to improve the realism of the tone.

The power supply consists of a half-wave rectifier using the rectifier section of V-102 with a 50-μf condenser for a filter. The keying control employs a pushbutton microswitch, a 25-μf condenser, and a relay. Normally, the microswitch connects the 25-μf condenser to the power supply for charging it. When the pushbutton is depressed, the switch disconnects the charged condenser from the power supply and connects it across the relay coil. The discharge of the condenser through the coil causes the relay to close its contacts momentarily so that the output tube V-102A transmits an echo tone. An adjustable shunt consisting of a 400-ohm fixed resistor in series with a 10,000-ohm rheostat shortens the time that the relay contacts are held closed. A 10,000-ohm resistor is included in the circuit through which the condenser is charged so as to impose a delay between successive echo tones. The imposition of a time delay between successive echoes is intended primarily as a precaution against accidental double echoes.

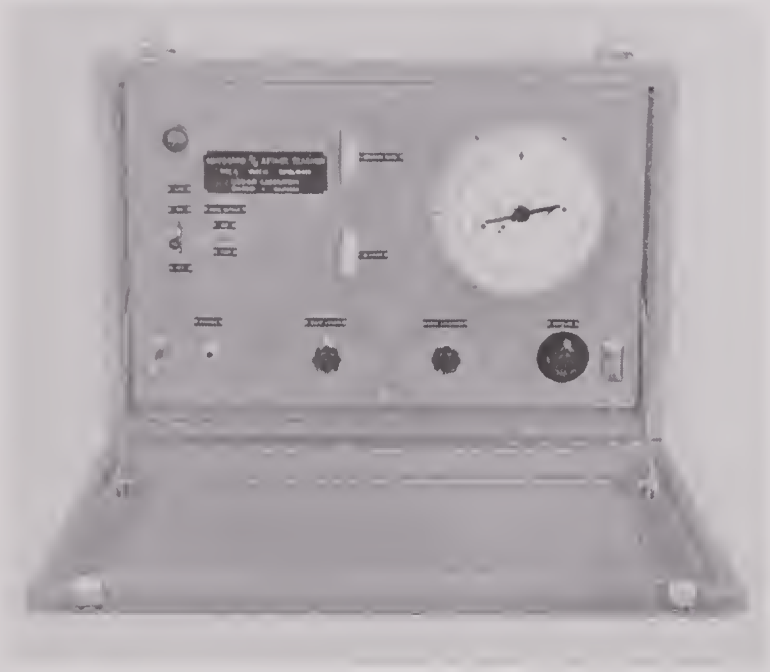


FIGURE 3. (SASAT-A), Model IV.

Shipboard Antisubmarine Attack Teacher

The shipboard antisubmarine attack teacher [SASAT-A], developed by the University of California, Division of War Research, at the U. S. Navy Radio and Sound Laboratory, San Diego, California, is a small portable device for introducing into shipboard QC echo-ranging equipment artificial echoes realistically simulating the conditions of an antisubmarine attack run. The echo injected can be so controlled as to indicate a submarine lying motionless, moving in any direction, changing course, remaining at a constant speed, altering speed, approaching the destroyer or moving away from it. By means of such controls, the destroyer conning officer can plan and conduct a practice attack, as well as drill sonar operators in making and developing a contact, determining bow cut-ons and target angles, estimating range and range rate, detecting evasive submarine maneuvers, and going through lost-contact procedures.

9.1 INTRODUCTION

SASAT-A was developed to provide sonar operators with practice at sea in detection of echoes and the use of the tactical range recorder. At the same time, it affords the conning officer practice in attacking evading enemy submarines. Since it is small, it may be left permanently connected to the echo-ranging gear of a ship and switched into action for sonar team practice at any time. When the SASAT is operating, the echo-ranging gear is essentially unaltered and continues to transmit signals and receive water noise and real echoes, if any.

As with echoes from a real target, those produced by the SASAT can be heard on the sonar loudspeaker, and can be translated into traces on the tactical range recorder to indicate range, range rate, and approximate target angle.

The SASAT-A is not entirely satisfactory as a training device because skill and familiarity with relative motion is required of the operator who sets the problem. Although he may use the instructor's manual, which furnishes complete instructions with tabulated charts and sketches for various kinds of training from simple doppler drills to highly complex runs involving the entire sonar team, the degree of realism achieved in the exercise depends primarily on his quickness in coordinating range rate, doppler, and echo length and intensity throughout a changing situation. A special SASAT slide rule, described elsewhere in this chapter, was developed to offset this difficulty by giving the range rates and the relative bearings of a submarine to a destroyer as functions of the distance between them. The experimental SASAT-B, incorporating an automatic problem generator, was therefore designed as a further improvement. SASAT-B is described in a later section.

WEA-1 and WEA-2 adapters, described later in this chapter, were designed so that SASAT-A could be used at Small Craft Training Centers on the type of sound equipment installed in small boats.

9.2 GENERAL DESCRIPTION

SASAT-A, Model IV, which served as the manufacturer's prototype, is shown in Figure 3. A *line* switch controls all leads into the echo-ranging gear. An *echo output* switch is used to monitor the echo so that it may be modified, if necessary, by the instructor, who listens with headphones plugged into the phone jack. When this switch is in the test position, the echo is heard only by the instructor, and when in the on position by both the instructor and the operator of the sonar equipment. A range dial controls the time between the signal sent out by the echo-ranging gear and the echo injected by the SASAT. A range-rate dial, automatically controlling the range dial, increases or decreases this time interval according to the range rate selected for the exercise. An echo length control determines the duration of the echo, so that short echoes can be used for beam attacks and longer ones for stern or bow attacks. The amplitude of the echo is similarly controlled by an echo loudness dial for near and far targets. A doppler dial controls pitch, and concentric bearing dials enable the instructor to indicate own-ship's true bearing course and set target relative to bearing. In addition, provisions are made within the apparatus for automatically increasing the target width as the range decreases and attenuating the echo at what would conform to the bearings of the right or left cut-ons.

A later experimental model of SASAT-A, Model V, incorporated modifications making the device usable with the BDI, and included a synchro-powered true bearing dial coupled to the ship's gyro. Dual signals were generated in Model V to simulate signals produced by a split projector. Moreover, the signals were generated at adjustable supersonic frequencies directly applicable to BDI and were delivered to the sonar equipment at the projector terminals. Model IV, on the other hand, generated echoes at audio frequencies and delivered them to the first audio stage in the QC receiver.

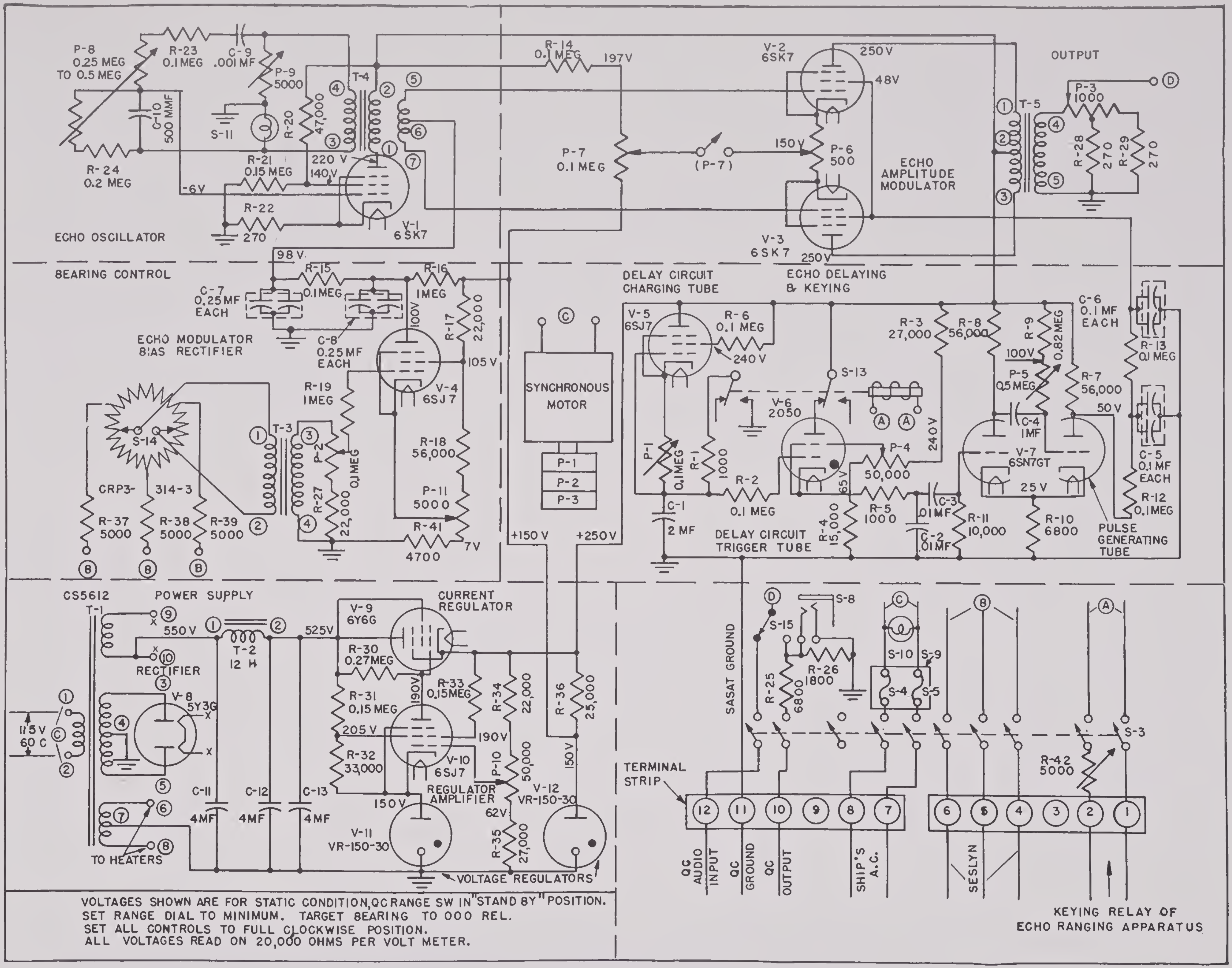
9.3 CIRCUIT DESCRIPTION (MODEL IV)

The keying of the relay which operates the transmitter in the echo-ranging apparatus is also utilized to activate a relay in the SASAT. After a time determined by the setting of its controls, the SASAT introduces into the audio system of the echo-ranging gear a simulated echo signal which can be detected by the sound operator if his projector is trained in a direction corresponding to the setting of the target-bearing dial on the SASAT.

The circuits governing these operations may be conveniently divided into six sections as indicated in the dotted-line boxes shown in the wiring schematic, Figure 4. These are the echo oscillator, the bearing control, the echo delay and keying, the output, the power supply sections, and the terminal strip connections.

Echo Oscillator Section

The simulated echo signal is developed in a resistance-capacitance stabilized oscillator V-1, with the oscillator frequency determined by the RC circuit consisting of capacitors C-9 and C-10 and a dual potentiometer P-8 and limited at the upper frequency by resistors R-23 and R-24. These resistors, together with the potentiometer P-9 and the thermistor S-11, form a


ECHO OSCILLATOR
P-8 0.25 MEG TO 0.5 MEG
R-23 0.1MEG
C-9 .001MF
P-9 5000
C-10 500 MMF
R-24 0.2 MEG
S-11
R-20
47,000
T-4
R-21 0.15 MEG
R-22 270
220 V
140V
-6V
V-1 6SK7
R-14 0.1 MEG
197V
P-7 0.1 MEG
(P-7)
150V
V-2 6SK7
250V
48V
P-6 500
ECHO AMPLITUDE MODULATOR
V-3 6SK7
250V
OUTPUT
P-3 1000
T-5
R-28 270
R-29 270
D
BEARING CONTROL
98V
R-15 0.1MEG
C-7 0.25MF EACH
C-8 0.25MF EACH
R-16 1MEG
R-17 22,000
100V
105 V
ECHO MODULATOR BIAS RECTIFIER
R-19 1MEG
V-4 6SJ7
S-14
T-3
P-2 0.1MEG
R-27 22,000
R-18 56,000
P-11 5000
R-41 4700
7V
CRP3-
314-3
R-37 5000
R-38 5000
R-39 5000
B
C
SYNCHRONOUS MOTOR
P-1
P-2
P-3
+150 V
+250V
DELAY CIRCUIT CHARGING TUBE
ECHO DELAYING & KEYING
V-5 6SJ7
R-6 0.1 MEG
240 V
S-13
V-6 2050
A
P-1 0.1MEG
R-1 1000
R-2 0.1 MEG
C-1 2 MF
DELAY CIRCUIT TRIGGER TUBE
R-4 15,000
65V
P-4 50,000
240V
R-5 1000
C-3 .01MF
C-2 .01MF
R-3 27,000
R-8 56,000
R-9 0.82 MEG
100V
P-5 0.5MEG
C-4 1MF
V-7 6SN7GT
25 V
R-7 56,000
50 V
R-11 10,000
R-10 6800
C-6 0.1 MF EACH
R-13 0.1 MEG
C-5 0.1 MF EACH
R-12 0.1MEG
PULSE GENERATING TUBE
CS5612
POWER SUPPLY
T-1
115V 60 C
550V
RECTIFIER
V-8 5Y3G
TO HEATERS
T-2 12 H
525V
C-11 4MF
C-12 4MF
C-13 4MF
V-9 6Y6G
CURRENT REGULATOR
R-30 0.27MEG
R-31 0.15 MEG
190V
205 V
R-32 33,000
R-33 0.15MEG
V-10 6SJ7
REGULATOR AMPLIFIER
190V
150V
V-11 VR-150-30
R-34 22,000
P-10 50,000
62V
R-35 27,000
R-36 25,000
150V
V-12 VR-150-30
VOLTAGE REGULATORS
SASAT GROUND
S-15
S-8
R-25 6800
R-26 1800
S-10
S-9
S-4
S-5
S-3
R-42 5000
TERMINAL STRIP
QC AUDIO INPUT
QC GROUND
QC OUTPUT
SHIP'S A.C.
SESLYN
KEYING RELAY OF ECHO RANGING APPARATUS

VOLTAGES SHOWN ARE FOR STATIC CONDITION,QC RANGE SW IN "STAND BY" POSITION.
SET RANGE DIAL TO MINIMUM. TARGET BEARING TO 000 REL.
SET ALL CONTROLS TO FULL CLOCKWISE POSITION.
ALL VOLTAGES READ ON 20,000 OHMS PER VOLT METER.

FIGURE 4. Electrical schematic for SASAT-A, Model IV.

bridge. The ratio of the resistance of the potentiometer P-9 to that of the thermistor S-11 determines the transmission at the resonant frequency. Since an increase in voltage causes a decrease in the resistance of the thermistor and therefore a decrease in the output of the bridge, the thermistor regulates the amplitude of the oscillation and thereby tends to stabilize the frequency of oscillation. The adjustability of the resistor P-9 permits the automatically maintained amplitude to be fixed at a desired value. The output transformer T-4 is provided with two secondary windings, one exciting the bridge, the other constituting part of a push-pull output circuit.

BEARING CONTROL

For proper operation of the SASAT, it is necessary to have a control device which will function with the selsyn system of the echo-ranging gear. The wires between the transmitting and receiving selsyns of this system carry information determined by the particular direction in which the projector mechanism is trained.

These voltages from the echo-ranging gear are supplied to the SASAT through a multiplier and the corrective resistors R-37, R-38, and R-39 to the ring potentiometer S-14. The rotating arms on the ring potentiometer, which are used to determine the potential at points 180 degrees apart, supply their output voltage through the transformer T-3, the voltage divider P-2, the resistor R-27, and the isolating resistor R-19 to the grid of the echo-modulator bias rectifier V-4. This tube acts as a delayed type rectifier in which the delay is controllable by the initial bias supplied by the potentiometer P-11. The output of V-4 supplies grid bias to tubes V-2 and V-3. A hum filter consisting of the condensers C-7 and C-8 and the resistor R-15 is inserted between tube V-4 and transformer T-4.

When the arms of the potentiometer S-14 are set in one position conforming to one position on the SASAT relative bearing scale, voltage will appear across them at all times except when the sound operator has trained his projector to the same bearing. At this time, no current will flow in tube V-4; furthermore, since V-4 controls the output section, the modulators V-2 and V-3 in that section will supply an echo signal to the audio section of the echo-ranging gear receiver.

When there is a slight difference between the bearings set on the SASAT and those on the echo-ranging gear, no effects will be observed because of the bias maintained by the potentiometer P-11, and the echo will still be heard. If there is a large difference, tube V-4 will begin to pass current, the potential at terminal 6 on T-4 will fall, and the transmission of the balanced modulator will be decreased, until finally the transmission of the modulator will drop to zero and no echo will be heard.

When the output signal is transmitted, current which operates the loudspeaker cutoff or meeting relay in the echo-ranging gear also actuates the SASAT relay S-13, which is connected to the thyratron V-6 and the delay circuit charging tube V-5. When relay S-13 is operated, the condenser C-1 is discharged to essentially zero voltage through the peak-current limiting resistor R-1, and tube V-6 is extinguished as its plate circuit is opened by additional relay contacts. As relay S-13 is released, condenser C-1 starts to charge at a rate determined by the charging current in tube V-5 and potentiometer P-1. This action proceeds until the grid of tube V-6 becomes sufficiently positive with respect to the ground, so that tube V-6 fires. Tube V-6 will continue to conduct until relay S-13 is again actuated by the transmitted pulse.

At the time of firing, the cathode of tube V-6 jumps positive because of the trigger action of the tube's gas content. This sudden rise is suitably shaped by the network comprising the resistors R-5 and R-11 and the condensers C-2 and C-3, so that a pulse is available a controllable time after the release of relay S-13. This delay corresponds to the delay between ping and echo, which measures the range of the target in normal echo-ranging procedure and is controlled by the value of the resistor P-1.

The keying pulse is finally supplied to a single-pulse multivibrator consisting of the two tubes making up V-7, the resistors R-7, R-8, R-9, R-10, and P-5 and the condenser C-4. It is a standard flip-flop multivibrator which, at the introduction of an input positive pulse produces an output pulse whose length is controlled by the charging time constant of a condenser C-4 and of resistors R-9 and P-5.

The keying pulse is supplied to the screens of tubes V-2 and V-3 through the network comprising the resistors R-12 and R-13 and the condensers C-5 and C-6. This network takes the high-frequency component out of the leading and lagging edges of the keying pulse and thus avoids the presence of "keying clicks" in the simulated echo signal. A synchronous motor which drives three potentiometers, P-1, P-2, and P-3, automatically adjusts echo amplitude and target width for range. A friction drive, adjustable by the range-rate control dial on the front panel, governs the speed at which the potentiometers rotate. P-1 controls the delay between signal and echo, thus increasing or decreasing the range according to the range rate selected, P-2 modifies the width of the relative bearing band over which the echo may be detected, and P-3 affects the amplitude of the echo.

Output

The output of the echo amplitude-modulator tubes, V-2 and V-3, drives the transformer T-5 and the attenuator P-3. This output circuit is connected to the audio stage of the echo-ranging gear receiver. As the keying potential applied to the screen grids of V-1 and V-2 approaches that of the plates, transmission occurs with a strength governed by the amplitude control P-7, which acts as a self-bias resistor, and the potential of the grid bias. The adjustable voltage divider P-6 serves to balance the modulator against any relative deviation of the characteristics of tubes V-2 and V-3.

Power Supply

The SASAT requires a power supply with constant d-c voltage output over a wide range of a-c input voltages. For these reasons the SASAT's power supply is of a regulated type.

SASAT-B was developed primarily to overcome the disadvantage of the series of manually operated controls characteristic of SASAT A. The simulated target is maneuvered by means of rudder and speed controls which provide automatically generated ranges and bearings, and a chart continuously shows the instructor the relative positions of ship and target together with ship's course. The doppler, attenuation, and other effects in the echo are also automatically introduced. Model I performed effectively in sea tests. Model II, which was intended to incorporate a number of improvements, was partially designed but had not reached the construction stage when the project was discontinued.

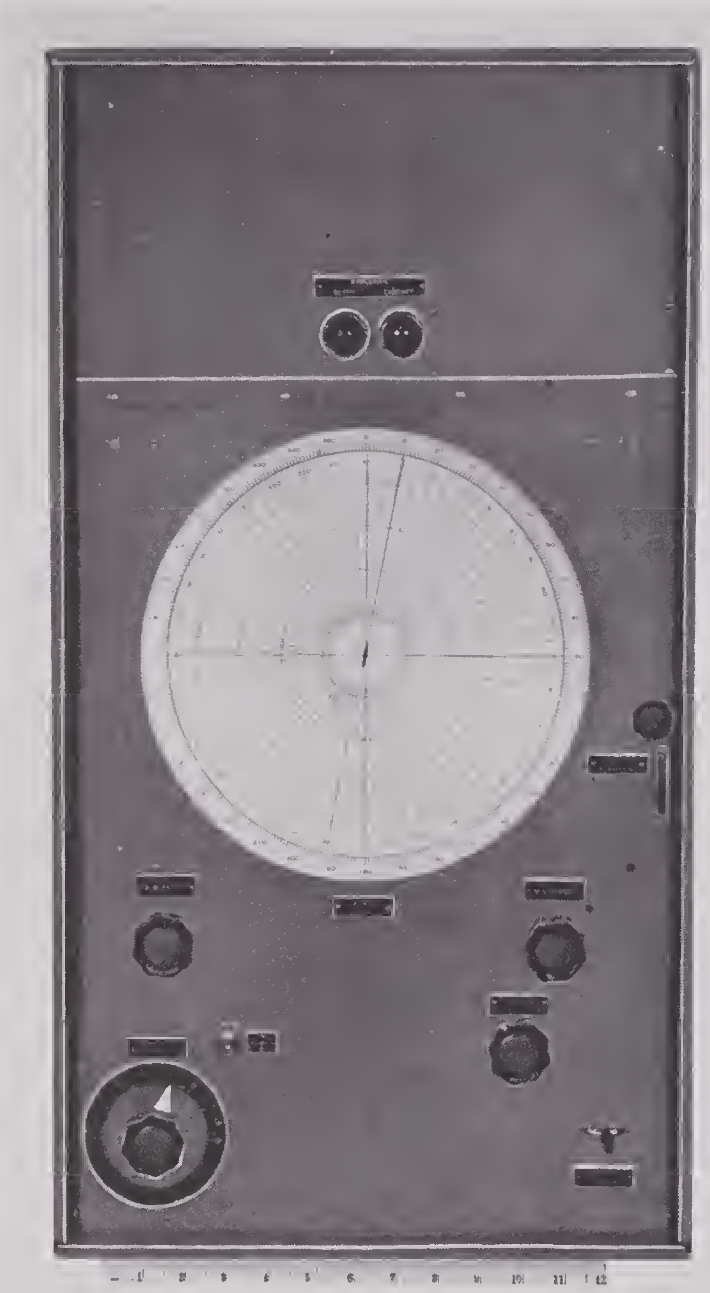


FIGURE 5. SASAT-B, Model I, Submarine operator's station.

Shipboard Antisubmarine Attack Teacher

The shipboard antisubmarine attack teacher [SASAT-B] is an improved version of SASAT-A with automatic problem generator features which make it less dependent for its effectiveness on the skill of the operator than is the manually controlled SASAT-A. Like SASAT-A, it is a portable instrument which introduces artificial echoes into QC echo-ranging gear for use in practice attack drills at sea. In operation, a simulated target is maneuvered by means of rudder and speed controls which provide automatically generated ranges and bearings. The doppler shift, attenuation, and other effects in the echo are also automatically introduced. Model I is housed in a metal cabinet with two control panels on opposite sides of the instrument. On the instructor's panel are indicators for target course and bearing, "depth charge" firing controls, explosion indicators and a large polar "scoring chart" which shows relative position of the target and attacking ship. By means of this chart, analysis of the final stages of an attack becomes possible. On the other panel, designed for an assistant or "submarine operator," are a submarine speed scale, a rudder and a depth control for use in conning the target, and a large polar chart showing the attacking ship's position relative to the target. Unless evasive maneuvers are required, an assistant is not needed; the controls on this panel can be preset to obtain any desired nonmaneuvering target course. The SASAT-B development was carried on by UCDWR.

9.4 GENERAL DESCRIPTION (MODEL I)

SASAT-B (Model I) is contained in a metal cabinet with two opposing panels. The panel designated as the submarine operator's station is shown in Figure 5. If the target is to follow a steady course, no operator is required at this station. The dials marked N-S preset and E-W preset are used to set the course, target speed is preset on the submarine speed scale, and target depth on the depth scale. The depth control determines the minimum range at which the echo is lost and the sinking time of the explosive charges when these are of the contact type.

If, on the other hand, the target is to engage in evasive tactics, an operator must man the controls at the submarine operator's station. He uses the submarine speed scale and the submarine rudder for conning the target. The polar chart in the center of his panel shows the submarine's course as a heavy line, and a pair of intersecting lines shows the position of the attacking vessel relative to the submarine. Range is marked off in 500-yd intervals to correspond to the rough estimate of range which a submarine sound operator can make. At the top of the panel is a pair of lights. Illumination of the red light represents the explosion of a

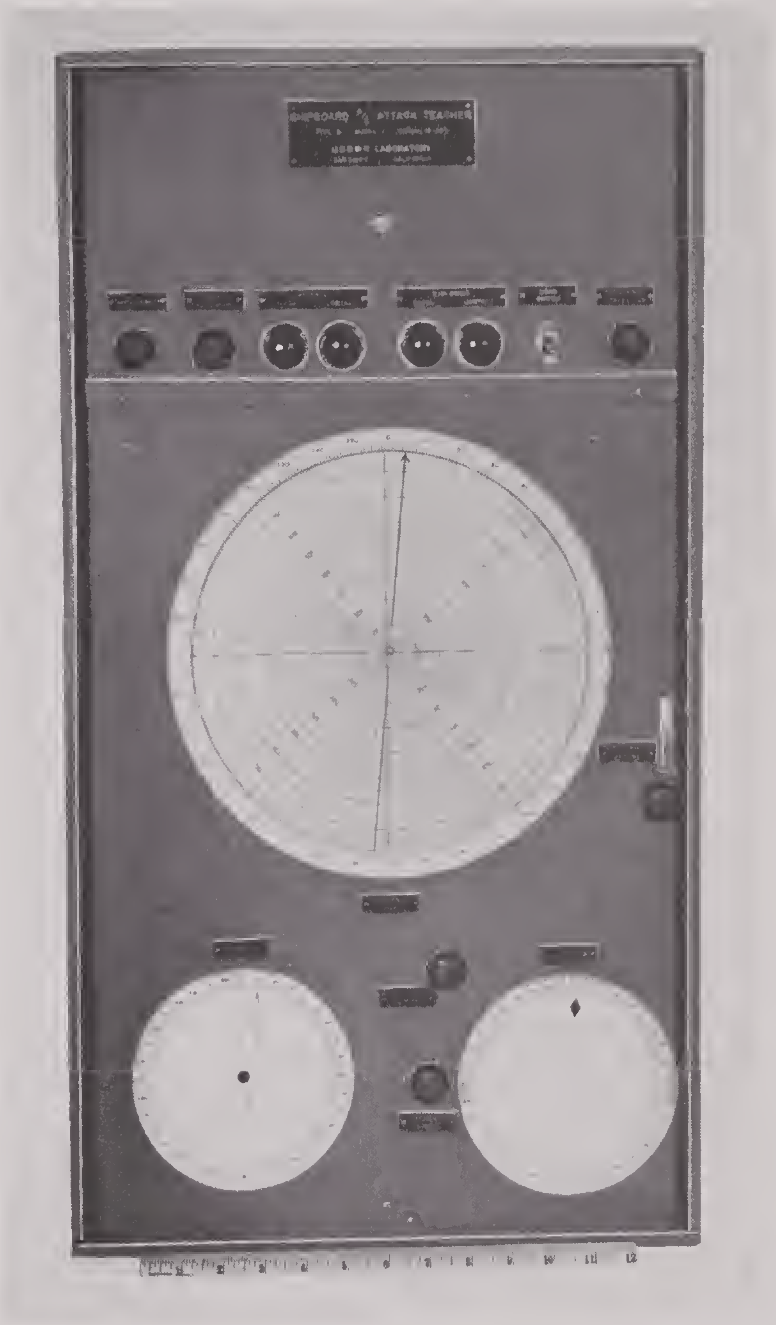


FIGURE 6. SASAT-B, Model I, instructor's station.

depth charge, and the green light glows when a contact charge has reached the submarine's depth.

The opposite side of the instrument, shown in Figure 6, is the instructor's station. The dials on this panel indicating submarine course and relative bearing are for reference only and should be kept invisible to the sonar operators and sound officers. In the center is a scoring chart similar to the one on the submarine operator's panel, except that in this case the destroyer's course is shown by the single heavy line (with the sound projector presumed to be at the center), and the relative position of the target is shown by the two intersecting lines. This chart, however, shows only the last 800 yd of the attack run and is used principally for evaluation. When a depth charge is released, the corresponding red light appears. An arrester or "memory" mechanism within the instrument removes the drive to this scale which comes from the maneuvering mechanism corresponding to the ship. Then, after a time corresponding to the depth charge setting which is made by the instructor, the red light marked "explosion" glows and the cross hairs stop completely. By comparing the position of these cross hairs with the position which they should occupy for a successful attack it is possible to measure the error in yards.

In the case of a contact charge, the green lights appear; the operation is identical except that it is the submarine's depth which controls the sinking time instead of the depth charge setting. At the top of the instrument is a release button which releases all the arresters and places the cross hairs in the position which they would have if an attack had not been completed. This is in order to make a reattack, if desired, without disturbing the maneuvering position.

There are also knobs for adjusting echo length and loudness and for correcting the frequency. Frequency correction for own-ship's doppler and for target doppler are automatic. The knob is used only for occasional adjustment.

When the ship has been maneuvered into a suitable attack position, the officer in charge of the attack may release a fire button which is located on a small box connected to the instrument by cable. This box also carries a knob for monitoring the ship's speed, so that the mechanism within the instrument will represent the ship's speed correctly at all times. The control box also carries a switch for shifting from contact charges to depth charges.

This machine was designed for a sinking time in seconds, as shown on the depth charge setting. It may thus be used with any type of depth charge. In the case of the contact charge this model was designed for mousetrap attack with the corresponding time of flight and a sinking time of 25 fps.

MECHANICAL DETAILS

Figure 7 is a mechanical schematic showing the function of the mechanical parts. The maneuvers of the ship and target are applied to a pair of ball-type component resolvers. Northings and eastings from the ship's resolver are subtracted from those of the target's resolver and the difference is fed to the scales; it is also fed to a mechanism which is used for controlling the range and bearing of the echo. The echo range is effected by varying a resistance with a chain-operated potentiometer. The bearing of the echo is determined by a disk on which a lobe-shaped commutator is installed which engages the contact that represents the target.

The relative bearing is fed into the instrument from a selsyn generator mounted on the ship's QC training mechanism. The selsyn motor within the instrument supplies this bearing to a differential which adds it to the ship's course supplied from a compass repeater; the output of this differential is the true bearing of the projector. This is applied to the scales and the ranging disk. It is also applied to another differential, together with the submarine's course. The output of this differential supplies target angle which is used to control the target doppler.

The ball component resolvers have proved to be a very satisfactory and simple means of analyzing the maneuvers. They are driven by permanent-magnet motors for speed-control purposes, the voltage of which is adjusted by the speed-control knobs. Another permanent-magnet motor supplies the turning of the submarine and has impressed on it the same voltage as the submarine's speed motor.

Each arrester used for scoring contains a pair of springs, which are preloaded to maintain a central position, and a clutch of the magnetic plate type. These arresters also have a threaded section for counting the number of turns lost, in the event the shaft travels more than one turn during scoring.

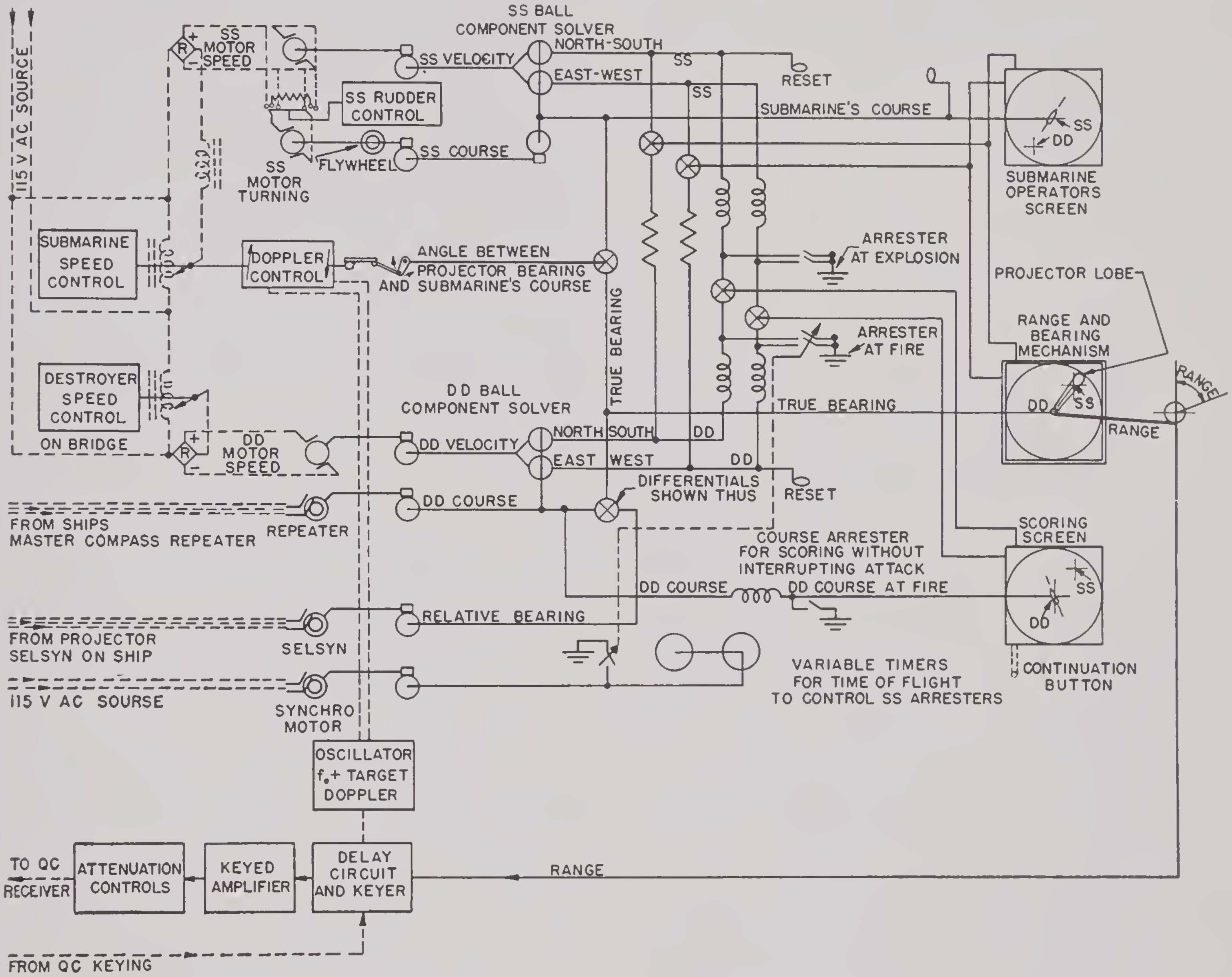

SS BALL
COMPONENT SOLVER
NORTH-SOUTH
EAST-WEST
SS VELOCITY
SS
SS
RESET
SS MOTOR SPEED
R
+
−
SS RUDDER CONTROL
SUBMARINE'S COURSE
FLYWHEEL
SS COURSE
SS MOTOR TURNING
115 V AC SOURCE
SS
DD
SUBMARINE OPERATORS SCREEN
SUBMARINE SPEED CONTROL
DOPPLER CONTROL
ANGLE BETWEEN PROJECTOR BEARING AND SUBMARINE'S COURSE
ARRESTER AT EXPLOSION
PROJECTOR LOBE
ARRESTER AT FIRE
RANGE AND BEARING MECHANISM
TRUE BEARING
DD BALL COMPONENT SOLVER
TRUE BEARING
RANGE
DD
SS
RANGE
DESTROYER SPEED CONTROL
ON BRIDGE
DD MOTOR SPEED
DD VELOCITY
NORTH SOUTH
EAST WEST
DD
DD
DIFFERENTIALS SHOWN THUS
RESET
DD COURSE
FROM SHIPS MASTER COMPASS REPEATER
REPEATER
COURSE ARRESTER FOR SCORING WITHOUT INTERRUPTING ATTACK
SCORING SCREEN
DD COURSE
DD COURSE AT FIRE
SS
DD
RELATIVE BEARING
FROM PROJECTOR SELSYN ON SHIP
SELSYN
VARIABLE TIMERS FOR TIME OF FLIGHT TO CONTROL SS ARRESTERS
CONTINUATION BUTTON
115 V AC SOURSE
SYNCHRO MOTOR
OSCILLATOR f_o+ TARGET DOPPLER
TO QC RECEIVER
ATTENUATION CONTROLS
KEYED AMPLIFIER
DELAY CIRCUIT AND KEYER
RANGE
FROM QC KEYING

FIGURE 7. Mechanical schematic for SASAT-B, Model I.

A mechanism is used in conjunction with the charts to present the position of the target as an intersection of a pair of lines at right angles. Each of these lines is painted across a sheet of cellulose nitrate which is mounted on a pair of rollers. The appearance of the chart is such that these crosslines appear to be drawn on the rotating course chart which is mounted behind them (see Figure 5). The same mechanism is used for both the submarine operator's chart and the scoring chart. Take-up springs of the type used in window shades absorb all backlash and the mechanism proves to be accurate. It is much more compact than an equivalent optical system and is also free from trigonometric error.

The position at which echo is lost is controlled by a microswitch actuated by two cams, one on the submarine depth shaft and the other on the range shaft. These cams are so designed that it is possible to hear an echo at long ranges, but the echo is lost at short ranges, the point at which it is lost being determined by the submarine's depth. A telechron motor is used for timing the intervals between release and explosion.

ELECTRICAL DETAILS

The echo simulator employed in Model I is designed for use in conjunction with *own-doppler nullifier* [ODN] equipment. The echo seems to be more closely simulated by the output of a positive bias multivibrator than by that of a pure wave oscillator. A multivibrator oscillator is, therefore, used as an echo generator, the frequency of which is controlled by the voltage drop across a bridge circuit, R-3 and R-4 of Figure 8. This voltage is a function of target angle and target speed and varies the frequency of the echo generator over the target-doppler range. A panel adjustment, R-34 of Figure 8, varies the base frequency of the echo generator so that it may be matched to the beat frequency of the QC receiver at zero doppler. After this initial adjustment has been made, target-doppler variations are automatically made.

V-8, V-9, and V-10 (Figure 8) comprise the echo delay and timing circuit. This circuit is actuated by a relay energized from the same source as the QC ping relay. This relay, S-1, deionizes V-9 and discharges C-5 while the ping is transmitted. When the contacts open at the end of the ping transmission, C-5 charges through V-8 at a rate determined by the resistance of R-15. The latter is varied mechanically by target range. When the charge across C-5 reaches the ionizing potential of the thyratron V-9, the latter fires, applying a positive potential to the grid of the trigger circuit V-10. As a result, a relatively high current flows through R-21 and R-22. Inasmuch as R-21 is common to both halves of V-10, this current develops a bias, causing the current in R-23 to fall to zero. The voltage drop across R-23 determines the cutoff bias of the keyed amplifier, V-12 and V-13. Consequently, when this bias is removed, the keyed amplifier passes the multivibrator output. Echo length is determined by constants of the circuit, comprising C-8, R-22, R-24, R-25, and controlled by R-25.

The output of the keyed amplifier is roughly attenuated by R-37 and then fed to a probe disk attenuator, which further reduces the output voltage commensurate with range and projector bearing.

It will be noted from Figure 8 that Model I includes the use of a selsyn motor M-2 to transmit projector bearing to the equipment. The remote selsyn generator is mounted on the projector hoist column. (This practice is avoided in Model II because of difficulties encountered in running cables between decks on ship installations.)

When a charge is fired, the fire button is closed, performing the following functions.

1. Solenoid L-1 releases a synchronous timer motor, causing a cam to rotate a 1 rpm.
2. Destroyer brakes L-2, L-3, and L-4 are energized, isolating the motion of the destroyer from the scoring chart.
3. Relay X-1 is closed, lighting pilot lamp I-6, red, or I-5, green (depth or contact charge respectively).

The timer motor referred to above is electrically connected at all times, but its motion is halted by the solenoid arm. When the timer motor is released, the rotating cam engages either S-4 or S-5, depending on position of choice switch. The position of S-4 is adjusted in accord with the depth of submarine dial, while the position of S-5 is adjusted in accord with the time control on the released depth charge. When the cam contacts S-4 or S-5, coincidental with the hypothetical explosion, the following functions are performed.

1. L-5 and L-6 are energized, subtracting the motion of the submarine, thus indicating the position of the submarine when the charge exploded or reached the depth of the submarine.
2. X-3 is closed, lighting pilot lamps I-2 and I-4, red, or I-1 and I-3, green.

S-1 and S-2 are limit switches designed to open when the problem runs off the screen.

Z-1 is a selenium cell full-wave rectifier, supplying a permanent-magnet [PM] field, d-c motor M-4 which furnishes destroyer speed information to the ball solver described in the mechanical review. Its speed is governed by a remote Variac located on the bridge of the vessel.

The submarine speed is furnished by a similar motor M-5, and controlled by a Variac V via

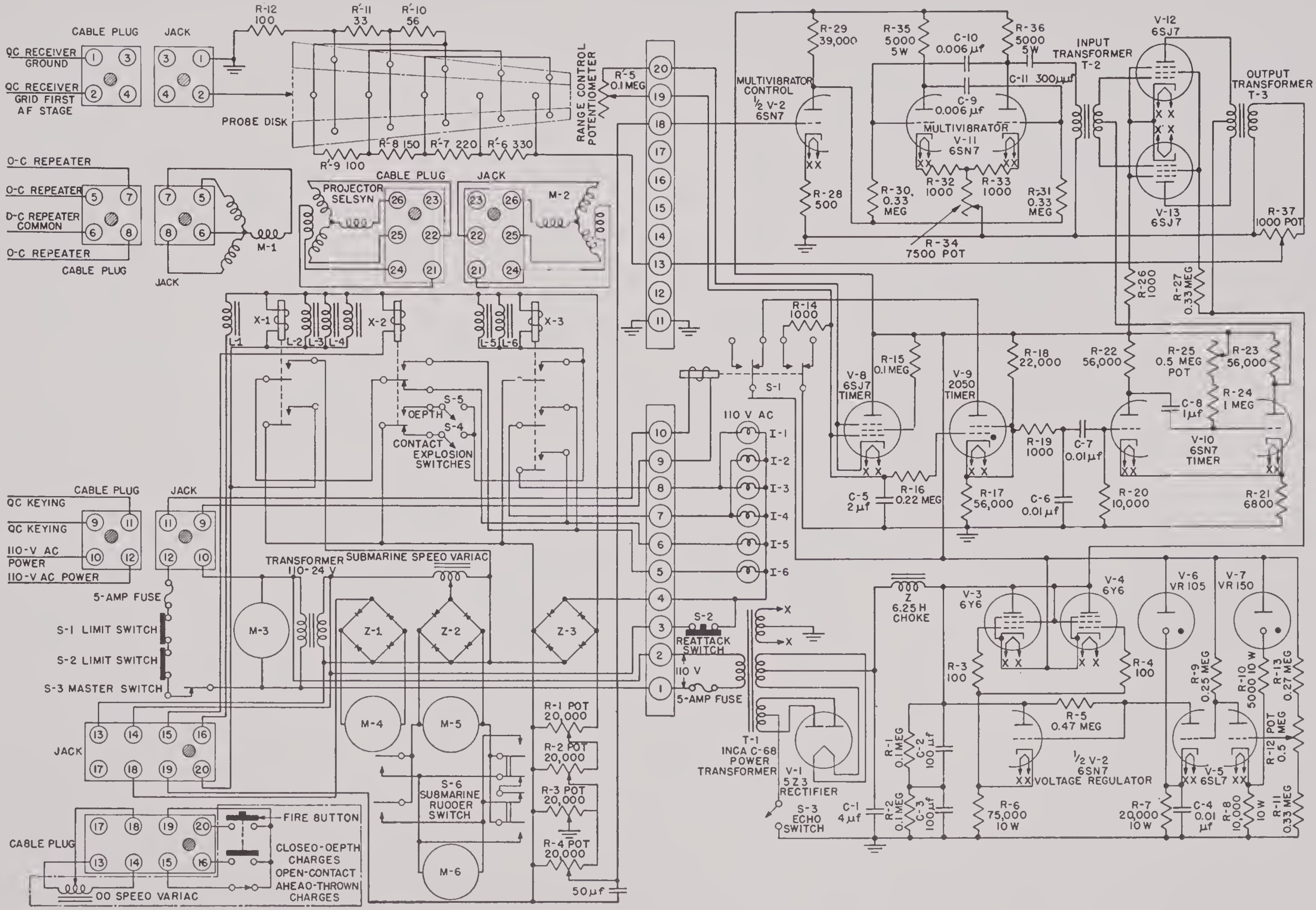

CABLE PLUG
JACK
QC RECEIVER GROUND
QC RECEIVER GRID FIRST AF STAGE
PROBE DISK
R-12 100
R'-11 33
R'-10 56
R'-9 100
R'-8 150
R'-7 220
R'-6 330
RANGE CONTROL POTENTIOMETER
R'-5 0.1 MEG
O-C REPEATER
D-C REPEATER COMMON
M-1
PROJECTOR SELSYN
M-2
X-1
X-2
X-3
L-1
L-2
L-3
L-4
L-5
L-6
S-5
DEPTH
S-4
CONTACT
EXPLOSION SWITCHES
QC KEYING
110-V AC POWER
5-AMP FUSE
S-1 LIMIT SWITCH
S-2 LIMIT SWITCH
S-3 MASTER SWITCH
TRANSFORMER 110-24 V
SUBMARINE SPEED VARIAC
M-3
M-4
M-5
M-6
Z-1
Z-2
Z-3
S-6 SUBMARINE RUDDER SWITCH
R-1 POT 20,000
R-2 POT 20,000
R-3 POT 20,000
R-4 POT 20,000
50 μf
FIRE BUTTON
CLOSED-DEPTH CHARGES
OPEN-CONTACT AHEAD-THROWN CHARGES
DD SPEED VARIAC
MULTIVIBRATOR CONTROL ½ V-2 6SN7
R-29 39,000
R-28 500
R-35 5000 5W
C-10 0.006 μf
R-36 5000 5W
C-9 0.006 μf
C-11 300 μμf
MULTIVIBRATOR V-11 6SN7
R-30 0.33 MEG
R-32 1000
R-33 1000
R-31 0.33 MEG
R-34 7500 POT
INPUT TRANSFORMER T-2
V-12 6SJ7
V-13 6SJ7
OUTPUT TRANSFORMER T-3
R-37 1000 POT
R-26 1000
R-27 0.33 MEG
R-14 1000
S-1
110 V AC
I-1
I-2
I-3
I-4
I-5
I-6
V-8 6SJ7 TIMER
R-15 0.1 MEG
C-5 2 μf
R-16 0.22 MEG
V-9 2050 TIMER
R-17 56,000
R-18 22,000
R-19 1000
C-7 0.01 μf
C-6 0.01 μf
R-22 56,000
R-25 0.5 MEG POT
C-8 1 μf
R-23 56,000
R-24 1 MEG
V-10 6SN7 TIMER
R-20 10,000
R-21 6800
S-2 REATTACK SWITCH
110 V
5-AMP FUSE
T-1 INCA C-68 POWER TRANSFORMER
V-1 5Z3 RECTIFIER
S-3 ECHO SWITCH
C-1 4 μf
Z 6.25 H CHOKE
V-3 6Y6
V-4 6Y6
R-3 100
R-4 100
R-1 0.1 MEG
C-2 100 μf
R-2 0.1 MEG
C-3 100 μf
R-5 0.47 MEG
½ V-2 6SN7 VOLTAGE REGULATOR
R-6 75,000 10 W
V-6 VR 105
V-7 VR 150
R-9 0.25 MEG
R-10 5000 10 W
R-13 0.27 MEG
R-12 POT 0.5 MEG
V-5 6SL7
R-7 20,000 10 W
C-4 0.01 μf
R-8 10,000 10 W
R-11 0.33 MEG

FIGURE 8. Electrical and echo simulator schematic for SASAT-B, Model I.

a second selenium cell rectifier Z-2. A third PM field motor M-6 is connected in parallel with M-5 through a reversing switch for rudder information. By this means the submarine can be conned, its turning rate being proportional to its speed. A flywheel makes the action sluggish in accord with actual conditions. In the off position M-6 acts as a generator, the output of which is shorted to achieve a braking effect.

Z-3 furnishes a voltage to four potentiometers which produce the voltage for controlling own-doppler frequency.

9.5 GENERAL DESCRIPTION (MODEL II)

Although Model II of SASAT-B remained in the design stage, it is believed that a number of valuable improvements were projected which should be considered in any future development.

This model in general is simpler, since it is designed for one-man operation. The two opposing panels of Model I had sometimes been found inconvenient for installation on shipboard. It seemed quite feasible for the instructor to maneuver the target in addition to his other duties, and Model II therefore has only one control panel. In the scoring on this instrument it was likewise decided not to include the arrester mechanism. The scoring may be done so rapidly that it was felt that an insignificant time would be lost and that, in bringing ships about for a reattack, there would be a negligible error.

Other simplifications were envisaged in the form of additional automatic features. It was expected to include the characteristic effects on the *bearing deviation indicator* [BDI], where such equipment was part of the echo-ranging gear. A doppler control of the sonic speedometer type was planned, so that reverberations would govern the speed of the virtual attacking ship within the instrument and, at the same time, render the doppler automatic. (For a discussion of the various methods of producing doppler effects in the simulated echo, see the bibliography.[1]) The echo length would have been made to vary automatically with changes in ping length and target angle. To simulate the error in the indicated range on the range recorder during stern attacks, it was planned to couple a range compensator to the shaft which varies the target doppler in accordance with target angle variations.

Figure 9 shows the control panel designed for Model II. The ship is at the center of the 12-in.-sq chart, and its course is represented by the heavy black line which crosses the chart. On an outer ring which rotates with this line, relative bearings may be read. True bearings appear on an inner azimuth ring engraved on the back of the transparent window. Target position is shown at the intersection of a pair of crosslines, and projector bearing is represented by a lobe-shaped pointer, with range graduations, painted on a transparent disk.

This projector bearing pointer may be "borrowed" by the instructor, using the knob marked *indicator*, whenever he wishes to measure target range and bearing, as, for example, at the moment of "fire one." At the same time, as part of the scoring, he can record the courses and speeds of the vessels while pressing the release button so that the maneuvering may continue within the instrument. Except when the indicator knob is on, the projector bearing pointer is controlled through a selsyn-line interconnector by the sound operator as he trains his projector.

On the lower part of the panel are the conning controls and dials for monitoring the ship's speed. The latter are used for conning the instrument's hypothetical ship separately from the real ship, if this should be desired temporarily in preference to maneuvering the real ship. Knobs are also provided for occasional correction of echo frequency, length, and loudness, features which are automatic during actual operation.

MECHANICAL DETAILS

Figure 10 is a schematic showing the functional operation of the mechanical components in Model II. The same type of component analyzer is employed as that used in Model I except that the mechanism is driven by a synchronous motor through variable speed controls. This is done so that a high degree of linearity in the speed control will be present since it is desired to employ this in connection with the doppler control.

Shown in the schematic at *M* is a motor for varying own-ship's speed. It is intended that this motor be controlled by a frequency dis-

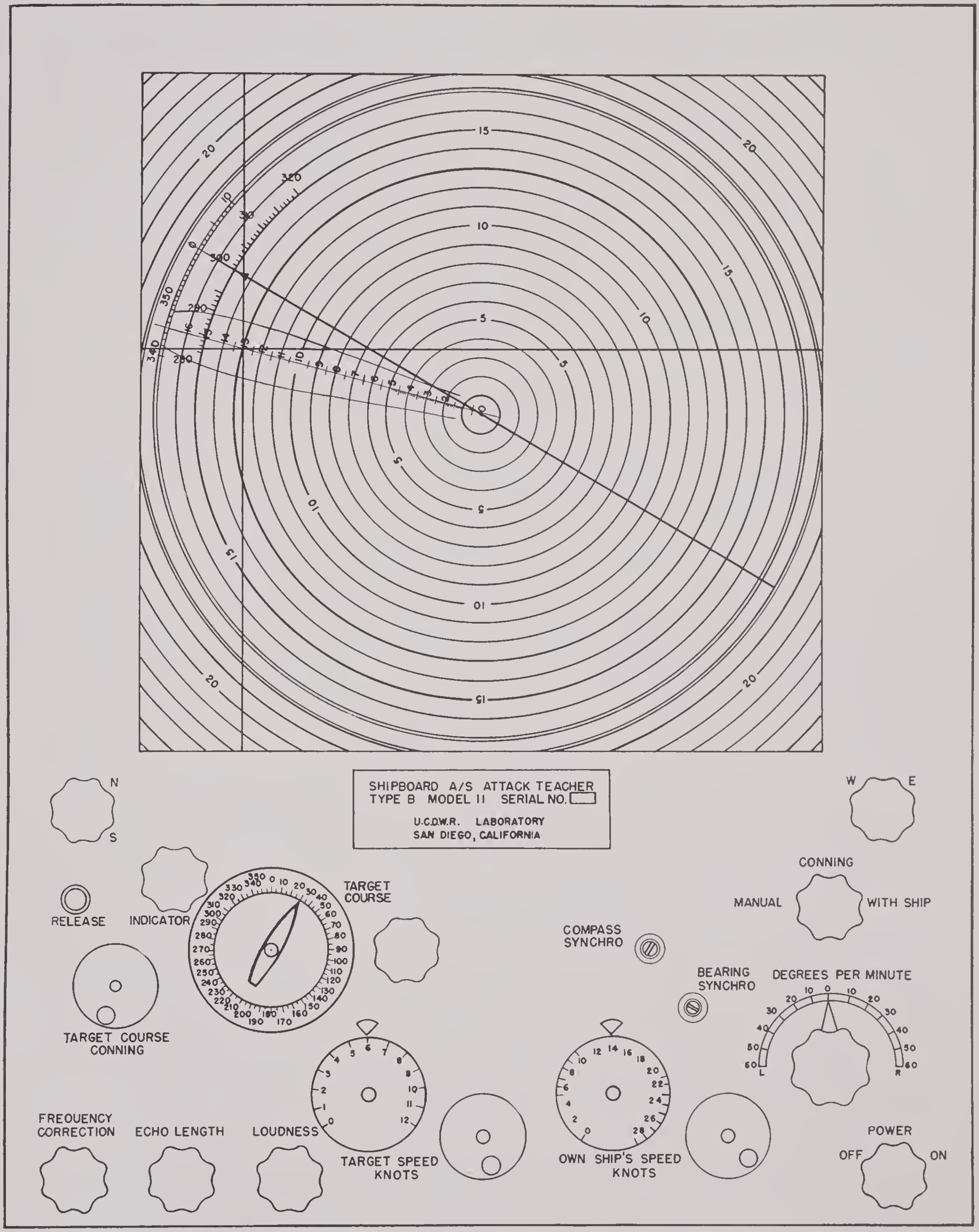

N
S
W
E
SHIPBOARD A/S ATTACK TEACHER
TYPE B MODEL II SERIAL NO.
U.C.D.W.R. LABORATORY
SAN DIEGO, CALIFORNIA
CONNING
MANUAL
WITH SHIP
RELEASE
INDICATOR
TARGET COURSE
COMPASS SYNCHRO
BEARING SYNCHRO
DEGREES PER MINUTE
L
R
TARGET COURSE CONNING
FREQUENCY CORRECTION
ECHO LENGTH
LOUDNESS
TARGET SPEED KNOTS
OWN SHIP'S SPEED KNOTS
POWER
OFF
ON

Figure 9. SASAT-B, Model II, control panel.

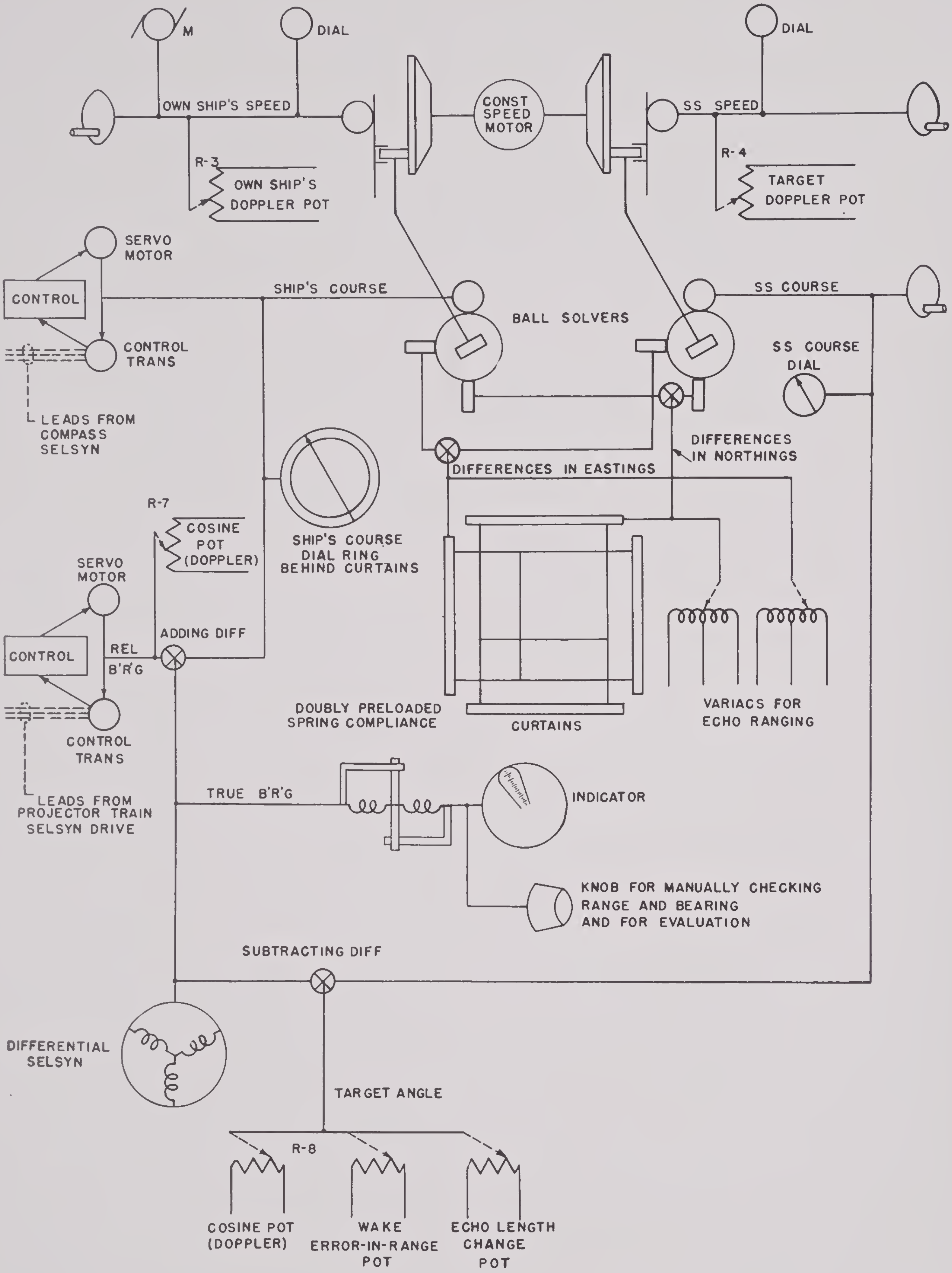

M
DIAL
DIAL
OWN SHIP'S SPEED
CONST SPEED MOTOR
SS SPEED
R-3
OWN SHIP'S DOPPLER POT
R-4
TARGET DOPPLER POT
SERVO MOTOR
CONTROL
CONTROL TRANS
LEADS FROM COMPASS SELSYN
SHIP'S COURSE
BALL SOLVERS
SS COURSE
SS COURSE DIAL
DIFFERENCES IN NORTHINGS
DIFFERENCES IN EASTINGS
R-7
COSINE POT (DOPPLER)
SHIP'S COURSE DIAL RING BEHIND CURTAINS
SERVO MOTOR
CONTROL
REL B'R'G
ADDING DIFF
CONTROL TRANS
LEADS FROM PROJECTOR TRAIN SELSYN DRIVE
DOUBLY PRELOADED SPRING COMPLIANCE
CURTAINS
VARIACS FOR ECHO RANGING
TRUE B'R'G
INDICATOR
KNOB FOR MANUALLY CHECKING RANGE AND BEARING AND FOR EVALUATION
SUBTRACTING DIFF
DIFFERENTIAL SELSYN
TARGET ANGLE
R-8
COSINE POT (DOPPLER)
WAKE ERROR-IN-RANGE POT
ECHO LENGTH CHANGE POT

FIGURE 10. Mechanical schematic for SASAT-B, Model II.

criminator circuit so that in producing a base oscillator frequency, which matches the reverberation frequency in the water, the motor will at the same time measure the speed of the actual attacking ship and correct the virtual attacking ship's speed to the same value.

Instead of the chain-drive potentiometer used in Model I, a much simpler ranging mechanism has been developed. The northing and easting outputs from the resolvers drive Variacs, while the bearing mechanism drives a differential selsyn. The relation of these Variacs to the selsyn which controls the echo is described in connection with the electrical details. This method was tested experimentally in its details, and seems to give great promise in simplifying the mechanical construction by eliminating the rather bothersome echo mechanism employed in Model I.

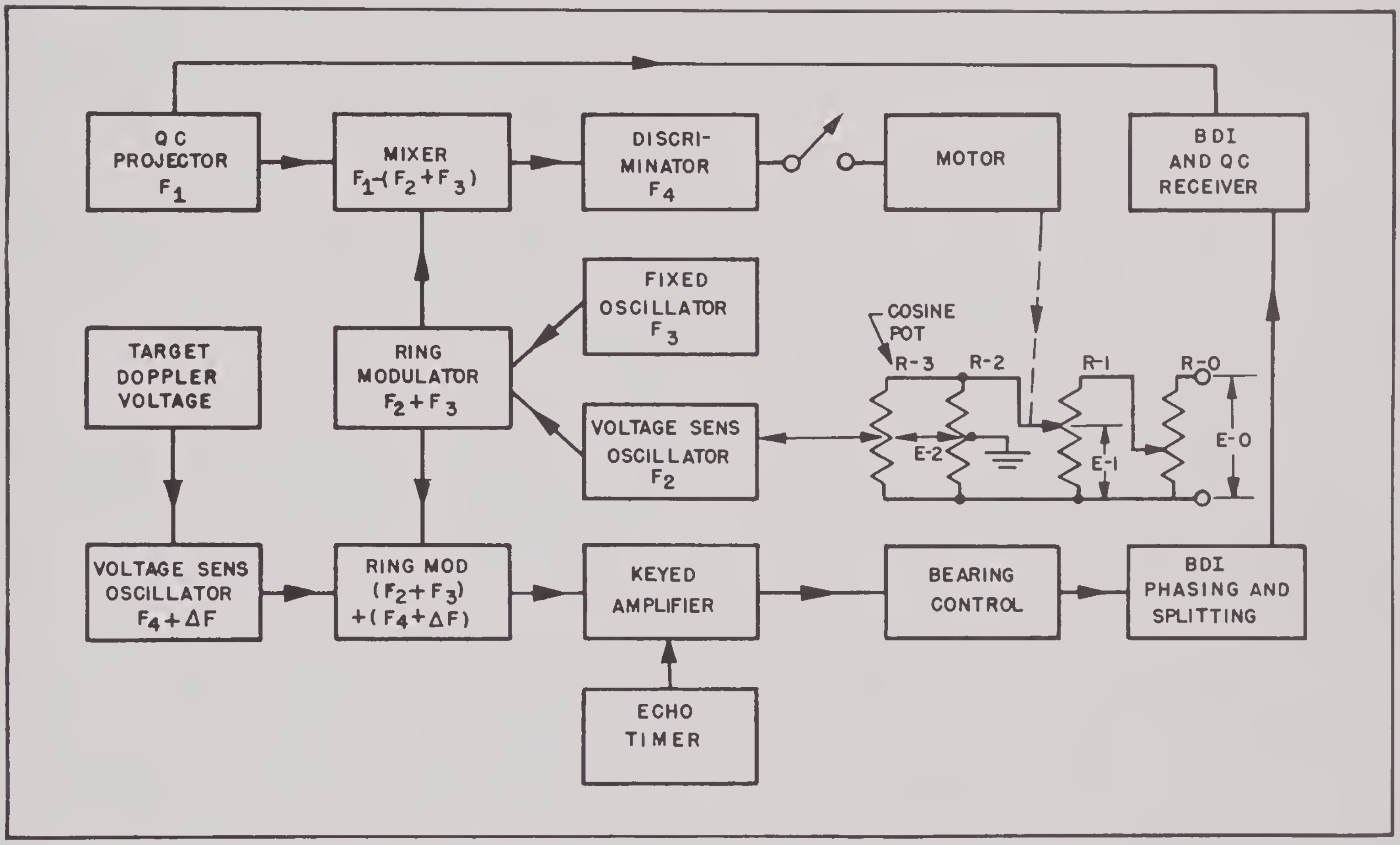

QC PROJECTOR F_1
MIXER $F_1-(F_2+F_3)$
DISCRIMINATOR F_4
MOTOR
BDI AND QC RECEIVER
FIXED OSCILLATOR F_3
COSINE POT
R-3
R-2
R-1
R-0
E-2
E-1
E-0
TARGET DOPPLER VOLTAGE
RING MODULATOR F_2+F_3
VOLTAGE SENS OSCILLATOR F_2
VOLTAGE SENS OSCILLATOR $F_4+\Delta F$
RING MOD (F_2+F_3) $+(F_4+\Delta F)$
KEYED AMPLIFIER
BEARING CONTROL
BDI PHASING AND SPLITTING
ECHO TIMER

FIGURE 11. Sonic speed control as a doppler compensator.

It was desired to make only electric connections to the ship from the instrument, and for this and other reasons control transformers and servo-motors are shown in this design for minimizing the amount of current drawn from the selsyn lines on the ship and, at the same time, for developing sufficient torque for operating the mechanism. The only connections which are made to the ship's gear are the connections to the training selsyn, the compass selsyn, and the sound gear itself. It was hoped that this system would take care of the automatic speed control of the virtual attacking ship without making additional connections to pitometers and other components.

ELECTRICAL DETAILS

In the proposed echo-simulating unit of Model II, a sonic speed control system was to be employed. In this system, own doppler is a direct function of the projector relative to bearing and the speed of the ship. The latter is difficult to determine accurately because of the number of variable factors involved. The sonic speedometer, however, shows promise of achieving an accurate result from own-doppler variations represented in water reverberations. At the same time it introduces own-ship's speed to the instrument's integrating mechanism.

In this system, as shown in Figure 11, a voltage-sensitive oscillator F_2 is mixed with F_3 and F_1 to form $F_1 - (F_2 + F_3)$, which is applied to a discriminator tuned to F_4. The polarized output of the discriminator is utilized to control a reversible motor driving a potentiometer R-1. The rotational displacement of R-1 from a zero position is made proportional to ship's speed and a dial connected to the potentiometer shaft reads ship's speed. (At the same time, this motor controls the speed of the virtual ship within the instrument.)

Again in Figure 11, E-1 is applied to a bridge circuit consisting of R-2 and R-3. R-2 is a center-tapped resistor, while R-3 is a potentiometer varied in accordance with the cosine of the relative projector bearing.

During the reverberation sampling period, relay *S* closes, performing the following functions.

1. Circuit consisting of R-1, R-2, and R-3 produces a voltage E-1, which is applied to the voltage-sensitive oscillator, F_2.
2. Direct current output of the discriminator is applied to the motor control.

Normally with the ship running at a constant speed, a variation of E-2 by R-3 will cause the same frequency displacement in F_2 as in F_1 ($\Delta F_1 = \Delta F_2$), and the corrected component $F_1 - (F_2 + F_3) = F_4$. However, if the ship's speed changes between ping samples, ΔF_1 and ΔF_2 will be different, causing $F_1 - (F_2 + F_3) = F_4$. Thus a properly polarized voltage will appear at the discriminator output. This will cause the motor to rotate, compensating R-1 until E-2 reaches a value sufficient to displace F_2 to the point where $F_1 - (F_2 + F_3) = F_4$. At this point, because of discriminator action, the motor will cut off and the speed dial will read the corrected speed of the ship. Frequency is corrected at the same time.

The sampling time is not critical and may be as long as reverberations suitable for correction purposes are available.

The time constant of the delay circuit should correspond to the time delay of the maximum echo range used. Target-doppler voltage is applied to a separate, voltage-sensitive oscillator, causing its frequency to be displaced from its base F_4 by an amount $\pm \Delta F$. This frequency $F_4 \pm \Delta F$ is then added to $F_2 + F_3$ in a ring modulator to form the doppler-compensated echo frequency. Inasmuch as ship's speed cannot change rapidly, previous objections voiced against motor control do not apply in this method.

Figure 12 is a schematic of the echo simulator which shows how the sonic speed-control system outlined above is incorporated. The doppler-corrected echo frequency is applied to the input of a keyed amplifier for echo-length and echo-delay timing. This is accomplished by a system similar to that used in Model I. The timed echo is then fed to two bearing-controlled keyed amplifiers for BDI phasing and range attenuation.

The latter functions are accomplished by the method outlined in Figure 13. The combination of the output voltages from northing and easting Variacs X-1 and X-2, after traversing the Scott transformer T-2, produce in the differential selsyn primary S-1 a 60-c single-phase field whose space orientation corresponds to the true bearing of the target vessel and whose magnitude is a measure of target range.

R-1 and C-1 are proportional, so that their impedances are equal at 60 c (the supply frequency) and serve in combination with T-3 to produce a voltage the magnitude of which is proportional to target range and independent of target bearing. The impedance of the network comprising R-1 C-1 is so chosen that the combination has a negligible effect on the voltages derived from X-1 and X-2.

The differential selsyn secondary S-2 is oriented angularly to correspond to the true bearing of the projector head. When acting in combination with the Scott transformer T-4, the selsyn produces an alternating voltage at point 1 which will be zero with respect to ground only when the projector is trained directly at the target or directly away from the target. The latter condition is an unwanted false null which is removed by the action of tubes V-2 and/or V-3 when they are served with the voltage developed at point 2. The voltage developed at point 1 is rectified by V-1 and V-4 to supply information for bearing and BDI operation. The small offset between right and left steered lobes of BDI is supplied by the center-tapped secondary 3 of T-4.

As a result of the above action negative potentials exist across R-2 and R-3 while the projector is trained away from the target.

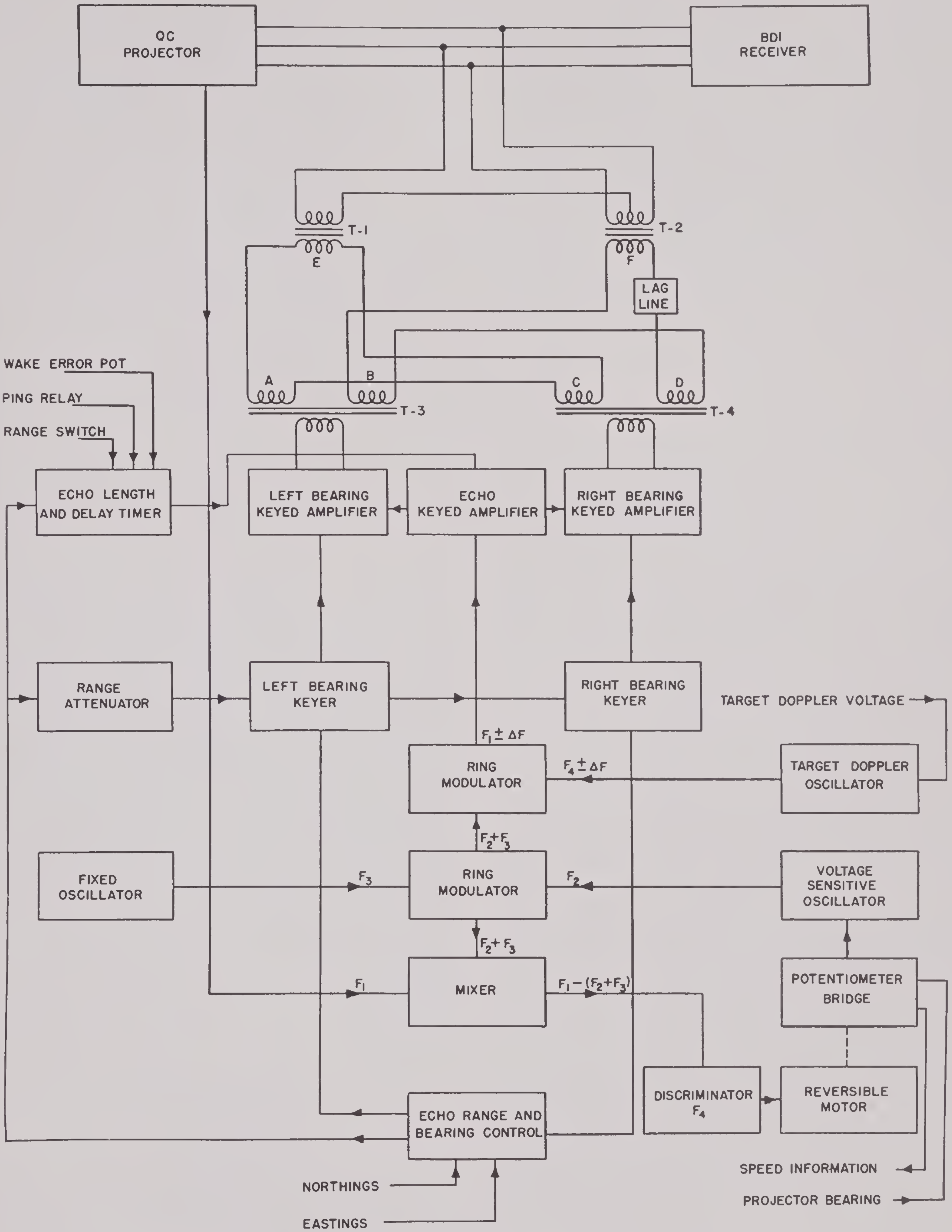

QC PROJECTOR
BDI RECEIVER
T-1
T-2
E
F
LAG LINE
A
B
C
D
T-3
T-4
WAKE ERROR POT
PING RELAY
RANGE SWITCH
ECHO LENGTH AND DELAY TIMER
LEFT BEARING KEYED AMPLIFIER
ECHO KEYED AMPLIFIER
RIGHT BEARING KEYED AMPLIFIER
RANGE ATTENUATOR
LEFT BEARING KEYER
RIGHT BEARING KEYER
TARGET DOPPLER VOLTAGE
$F_1 \pm \Delta F$
RING MODULATOR
$F_4 \pm \Delta F$
TARGET DOPPLER OSCILLATOR
F_2+F_3
FIXED OSCILLATOR
F_3
RING MODULATOR
F_2
VOLTAGE SENSITIVE OSCILLATOR
F_2+F_3
F_1
MIXER
$F_1-(F_2+F_3)$
POTENTIOMETER BRIDGE
DISCRIMINATOR F_4
REVERSIBLE MOTOR
ECHO RANGE AND BEARING CONTROL
SPEED INFORMATION
PROJECTOR BEARING
NORTHINGS
EASTINGS

FIGURE 12. Electrical schematic for SASAT-B, Model II, echo simulator.

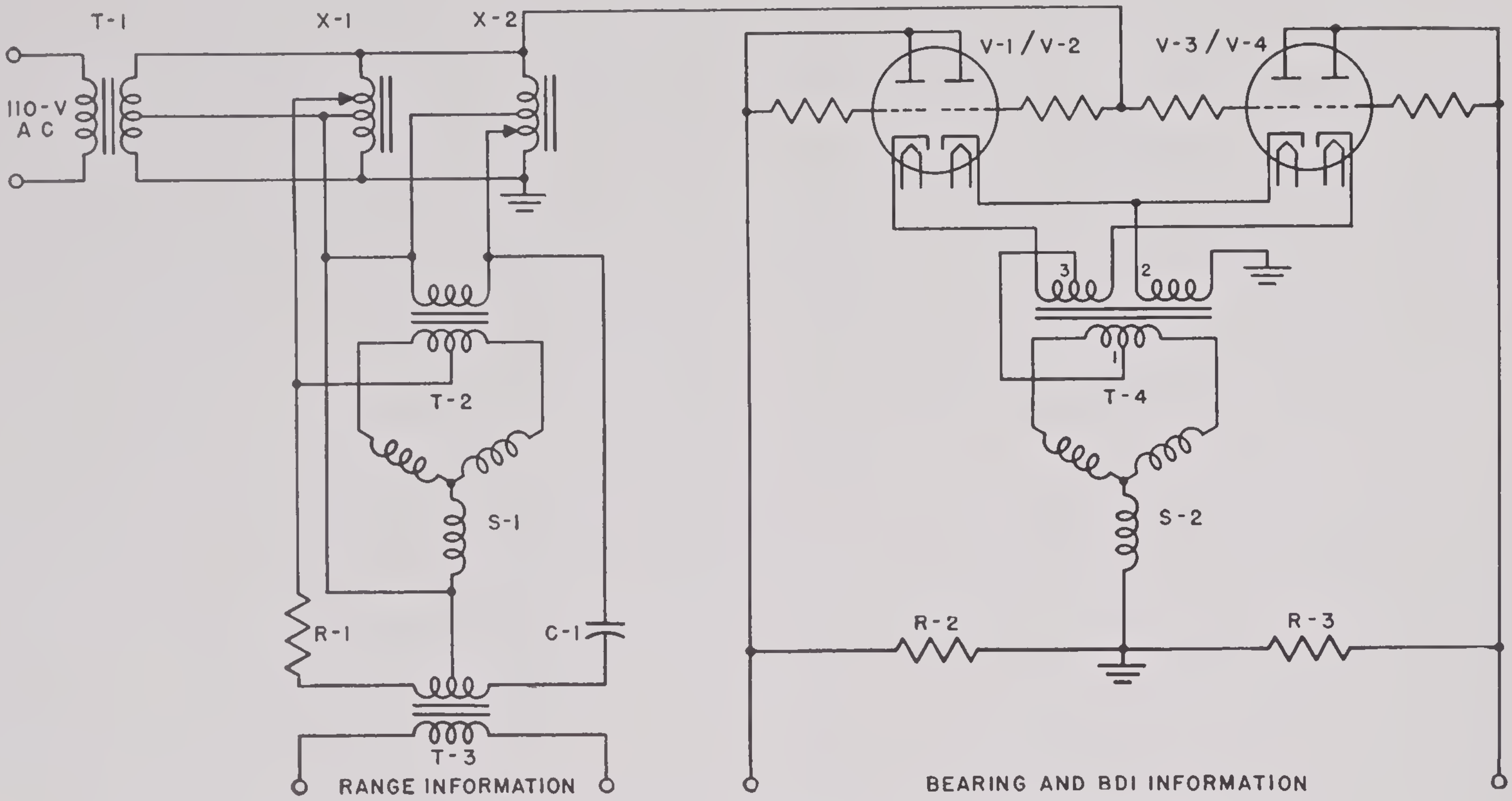

T-1
X-1
X-2
110-V AC
V-1/V-2
V-3/V-4
3
2
1
T-2
T-4
S-1
S-2
R-1
C-1
R-2
R-3
T-3
RANGE INFORMATION
BEARING AND BDI INFORMATION

Figure 13. Bearing and range control schematic, SASAT-B, Model II.

These voltages are applied to the right and left bearing-keyed amplifiers indicated in Figure 14 and are sufficient in magnitude to cause the amplifier tubes to cut off with echo signal applied.

As the projector is trained near the true bearing of the target, the voltages across R-2 and R-3 (Figure 13) will approach zero disproportionately, thus removing the cutoff biases and allowing the keyed amplifiers (Figure 14) to conduct the timed echo.

The disproportionate values of the applied biases (projector slightly off target bearing) cause the outputs of the two amplifiers to be of different magnitudes. When the projector is trained slightly to the right of the target bearing, the output of the right bearing amplifier will be greater than that of the left. The opposite is true when the projector is trained slightly to the left of the target bearing. Both amplifier outputs are equal and at a maximum when the projector is trained on the target.

Range attentuation is accomplished by limiting the screen grid current of the keyed amplifiers by the action of V-1 and V-2 as depicted in Figure 14.

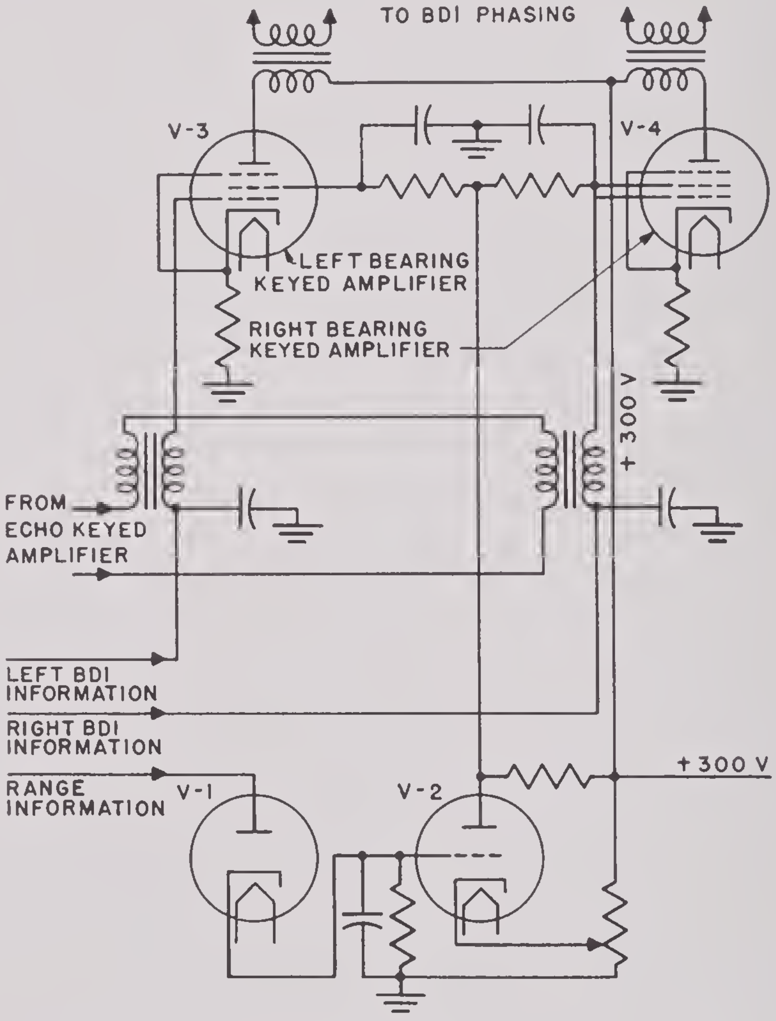

TO BDI PHASING
V-3
V-4
LEFT BEARING KEYED AMPLIFIER
RIGHT BEARING KEYED AMPLIFIER
+ 300 V
FROM ECHO KEYED AMPLIFIER
LEFT BDI INFORMATION
RIGHT BDI INFORMATION
RANGE INFORMATION
V-1
V-2
+ 300 V

Figure 14. Bearing keyer and range attenuator schematic, SASAT-B, Model II.

The timed and doppler-corrected echo is fed to a transformer network (Figure 12), which phases it properly for application to the BDI receiver. The voltage across winding *e* is the sum of the voltages *a* and *c* and represents the on-bearing component. Voltage across *f* is the differences between voltages *h* and *d*, and represents the right and left component. The voltage vector outputs of T-1 and T-2 are in quadrature because of the insertion of a lag line in the primary of T-2.

9.6 CONCLUSION

Shipboard trials of SASAT-B, Model I, successfully demonstrated the effectiveness of such a device for antisubmarine practice drills. The inclusion of the automatic target and scoring chart in Model II gave promise of even greater effectiveness, in that it supplied more realistic simulation of actual attack conditions and an accurate method of evaluating a practice run. In operations with an actual submarine target, misses cannot readily be analyzed. The scoring device in Model II is therefore a development of distinct value.

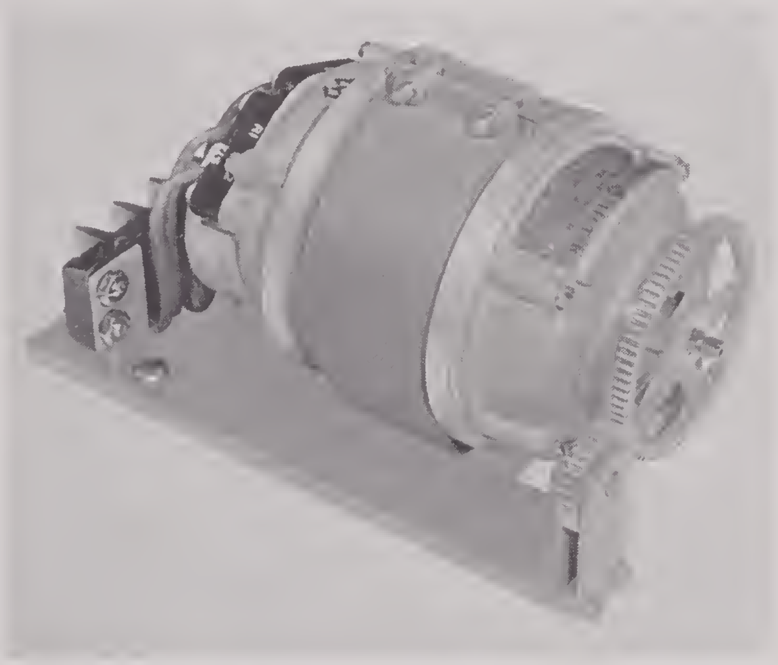


FIGURE 15. WEA-1 selsyn adapter unit (for use with SASAT-A).

WEA-1 and WEA-2 Adapters for SASAT-A

WEA-1 and WEA-2 adapters for SASAT-A, developed by UCDWR, were designed to adapt the shipboard antisubmarine attack teacher [SASAT-A] for use with the WEA-1 and WEA-2 sound equipment. These adapters are necessary because SASAT-A is designed for echo-ranging gear which employs a selsyn bearing repeater and a receiver muting relay not used in WEA-1 and WEA-2. The WEA-1 adapter provides a selsyn for gearing with the WEA-1 projector potentiometer to obtain bearing information for the SASAT; the WEA-2 adapter selsyn is chain-driven from the shaft of the WEA-2 projector hand-training wheel. The keying unit for both adapters operates the SASAT from voltage pulses developed at the time of the outgoing ping.

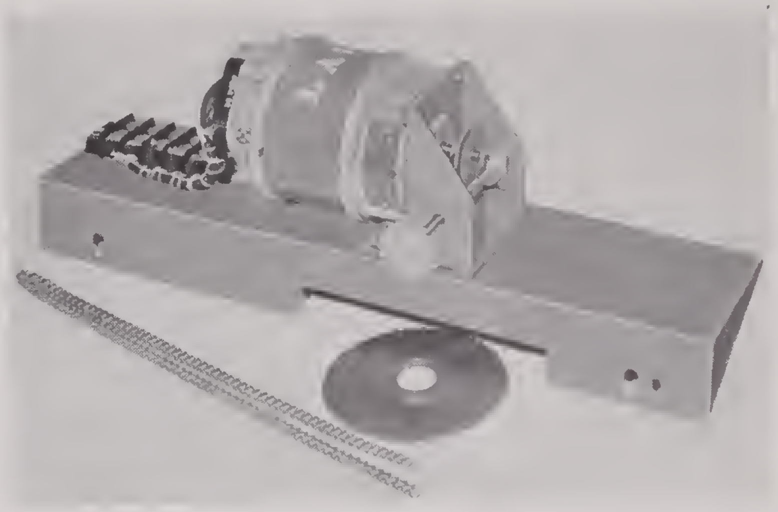


FIGURE 16. WEA-2 selsyn adapter unit (for use with SASAT-A).

9.7 WEA-1 SELSYN ADAPTER UNIT

In WEA-1 the rotation of the projector is controlled by means of a handwheel geared to a potentiometer, which forms one half of a bridge circuit for electric control of rotation. The other half of the bridge is another potentiometer which is geared to the projector training shaft. Any unbalance between these two potentiometers is amplified and operates two relays which control the rotation of the motor driving the projector shaft. A selsyn mounted on a plate with appropriate gears is therefore used to supply voltage to the SASAT in accordance with the projector bearing. This selsyn unit is installed on the chassis behind the remote-control unit to the right of the crankshaft and potentiometer. With the unit secured, the small gear (see Figure 15) meshes with the gear on the potentiometer. The small gear in turn drives the large gear so that the selsyn makes one complete revolution for every revolution of the projector.

9.8 WEA-2 SELSYN ADAPTER UNIT

In WEA-2 the rotation of the projector is controlled manually by means of a flexible cable. Figure 16 shows the selsyn and mounting plate for this type of gear. This adapter is installed inside the remote training control unit and connected by a chain and sprockets to the shaft of the training handwheel. The selsyn then makes one complete revolution for every revolution of the projector.

9.9 KEYING UNITS FOR WEA-1 AND WEA-2

WEA-1 and WEA-2 sound gear use either an electronic method of keying or relay-operated keying, neither of which is easily accessible. A small keying unit, shown in Figure 17, was therefore devised to operate from voltage pulses generated at the time of the outgoing ping. The circuit, illustrated schematically in Figure 18, employs a 117L7 tube. The diode portion T-1 is used to rectify the a-c line voltage to obtain plate voltage for T-2. C-1 filters out the ripple and R-4 is a divider across the supply. The coil of the relay in SASAT-A is connected between terminals 5 and 6 and the pulse obtained from the hand key on the WEA-1 or WEA-2 is supplied to terminals 3 and 4. T-2 is normally biased to cutoff, so that when the keying is supplied to the grid the tube draws current and the relay is actuated. R-1 is the grid isolating resistor, R-2 the grid return, and R-3 the screen-supply dropping resistor. Switch S-1 serves to change the bias on T-2 for the different types of keying, since WEA-2 keys from a minus voltage to ground, and WEA-1 keys from 0 voltage to a positive voltage. R-5 and the divided R-4 serve to supply the correct bias for these conditions. Because in general no ground return is available on the a-c line voltage system, one side must be grounded for the keying unit to function correctly. A 110-volt, 6-watt lamp (S-2) is used to determine which side of the line is grounded, if either. Therefore, connect the a-c voltage to terminals 1 and 2. If the lamp glows reverse the a-c connections. If the lamp is not lit, one side of the a-c system is grounded and the connections are correct. But if the lamp glows brightly with either connection it means that there is not a solid ground connection in the system. Therefore, either connection to terminals 1 and 2 should be made and terminal 2 should be connected to ground.

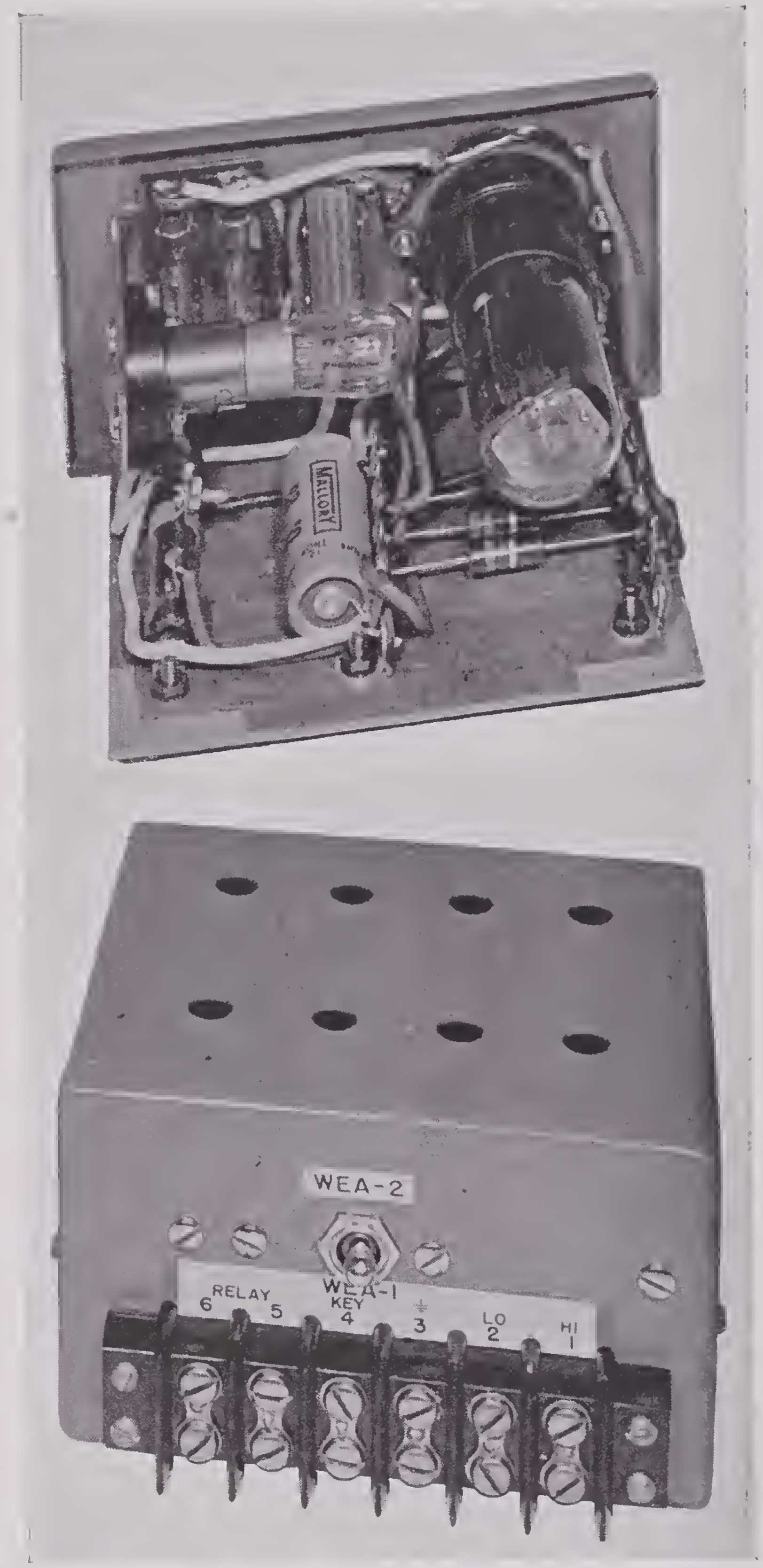


FIGURE 17. WEA-1 and WEA-2 keying adapter unit (for use with SASAT-A).

Since the WEA-1 gear has only one audio stage, a 10:1 step-up transformer is placed in the audio lead from the SASAT-A to the echo-ranging gear. This supplies enough voltage for the echo to have sufficient volume. Resistor R-40 of SASAT-A Model IV need not be used, as the transformer gives the isolation necessary when injecting into the audio system of WEA-1. In WEA-2 the transformer is not needed because two stages of audio amplification are used, but R-40 of SASAT-A must be increased to 820,000 ohms to give sufficient isolation.

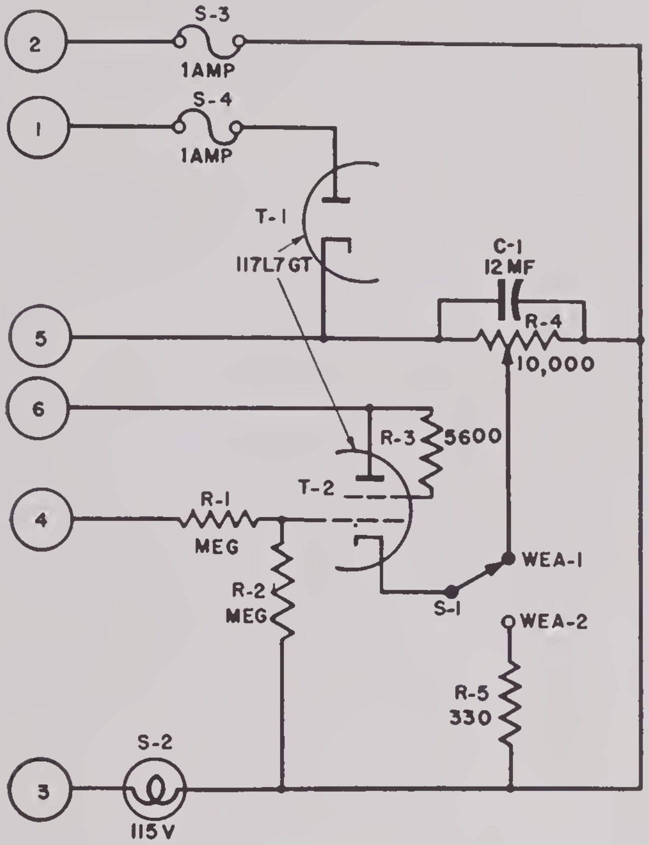

2
S-3
1AMP
1
S-4
1AMP
T-1
117L7GT
C-1
12 MF
5
R-4
10,000
6
R-3
5600
T-2
4
R-1
MEG
R-2
MEG
WEA-1
S-1
WEA-2
R-5
330
S-2
3
115V

FIGURE 18. Electrical schematic for WEA-1 and WEA-2 keying adapter unit.

Three versions of the slide rule were constructed, each being a simplification and improvement of its predecessor. The final model is shown assembled in Figure 19 and disassembled in Figure 20.

The bottom disk, 6 in. in diameter, carries the relative bearing scale and two angle T-1 dials, one for a 10-knot destroyer attacking a 4-knot submarine, and one for a 15-knot destroyer attacking a 4-knot submarine. In these dials the use of course angle is dropped in favor of the more familiar concept of target angle.

The bottom disk also carries two diagrams for use in calculating the proper angle T-1 from the original target angle T-0 and the amount and direction of the lead. On the angle T-1 dials the location of the numerical values has been rotated through 180 degrees.

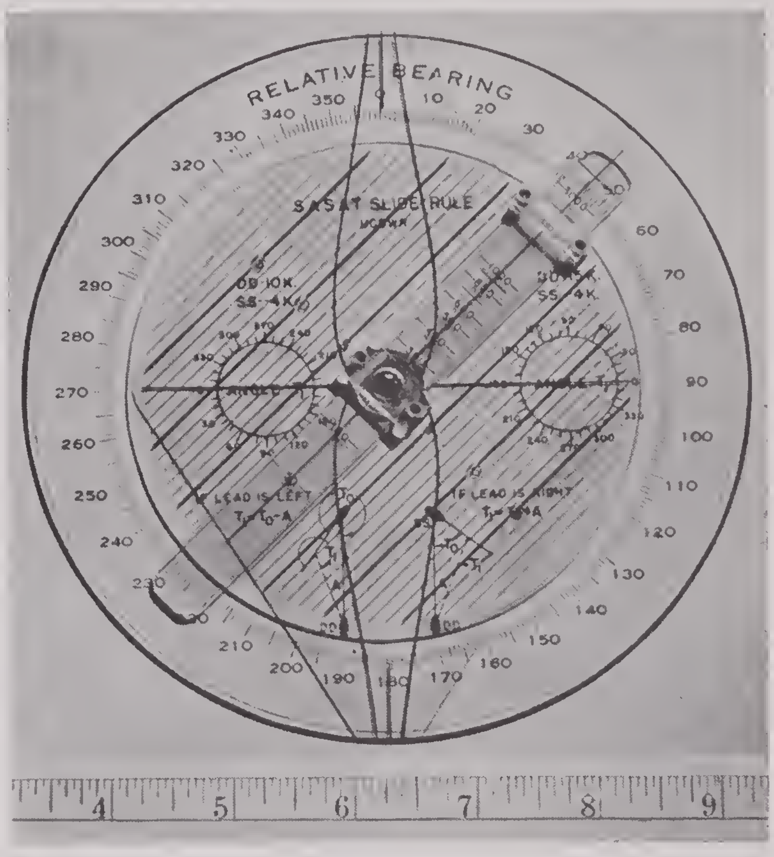

RELATIVE BEARING
SASAT SLIDE RULE
UCDWR
DD 10K
SS 4K
DD 15K
SS 4K
ANGLE T1
ANGLE T1
LEAD IS LEFT
IF LEAD IS RIGHT
0
10
20
30
40
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
230
240
250
260
270
280
290
300
310
320
330
340
350
4
5
6
7
8
9

FIGURE 19. SASAT slide rule.

SASAT Slide Rule

The SASAT slide rule is an instrument designed by UCDWR to assist the operator of a shipboard antisubmarine attack teacher [SASAT-A] in attaining rapid and accurate coordination in setting up a practice problem with the manually operated SASAT controls. However, it was used mainly for analyzing maneuvers at the close of practice periods. The main components of the instrument are a "bottom" disk, a movable disk and a cursor. The bottom disk is 6 inches in diameter and carries a relative bearing scale. The movable disk, 4-5 inches in diameter and made of transparent plastic, carries a pair of "cupid's bow" curves and an "index" line. The cursor, also made of transparent plastic, carries range and range rate scales and a "pointer" line. The slide rule is calibrated to give relative bearings and range rates as functions of the distance between a submarine and an attacking ship proceeding along straight courses at constant speeds.

Difficulties in determining the results of practice antisubmarine attacks led to the development of the practice attack meter system. In trials under actual training conditions, the practice attack meter showed itself to be a material improvement over earlier methods of evaluating attack runs. It has been suggested that, by providing rapidly a quantitative picture of performance, the meter might also be of value in appraisal of developments in attack or conning methods and systems.

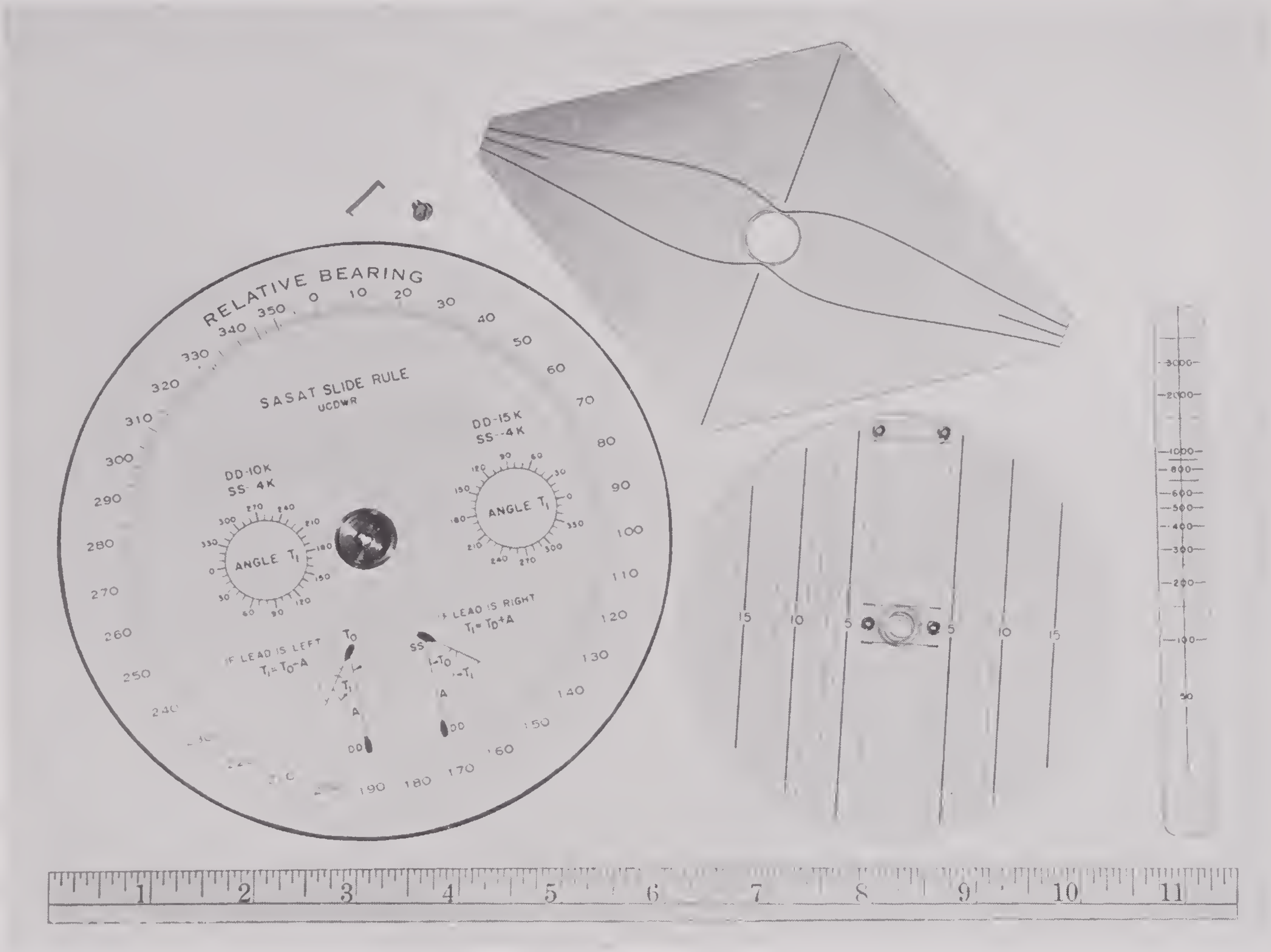

RELATIVE BEARING
SASAT SLIDE RULE
UCDWR
DD-10K
SS 4K
ANGLE T₁
DD-15K
SS-4K
ANGLE T₁
IF LEAD IS LEFT
T₁=T₀-A
IF LEAD IS RIGHT
T₁=T₀+A
T₀
T₁
A
SS
DD
15
10
5
5
10
15
3000
2000
1000
800
600
500
400
300
200
100
50
1
2
3
4
5
6
7
8
9
10
11

Figure 20. SASAT slide rule, disassembled.

9.10 OPERATING PROCEDURE

When the surface craft maneuvers into position for dropping a depth bomb, it releases a special projectile which is part of the practice attack meter system. This projectile carries a small explosive charge which is fired by water pressure at a depth at which the practicing submarine operates. The charges are intended to produce, as nearly as possible, uniform explosive pressures.

The impulse generated by the exploding charge is picked up by a directional hydrophone on the bridge of the submarine. In the resulting electric impulse, amplified and recorded by a meter, two components furnished by quadrature elements in the hydrophone are used to determine the bearing of the explosion relative to the submarine. Distance of the explosion from the submarine is determined by the intensity or amplitude of the impulse reaching the hydrophone. These range and bearing determinations are made by associating and interpreting the meter readings on a calculating chart.

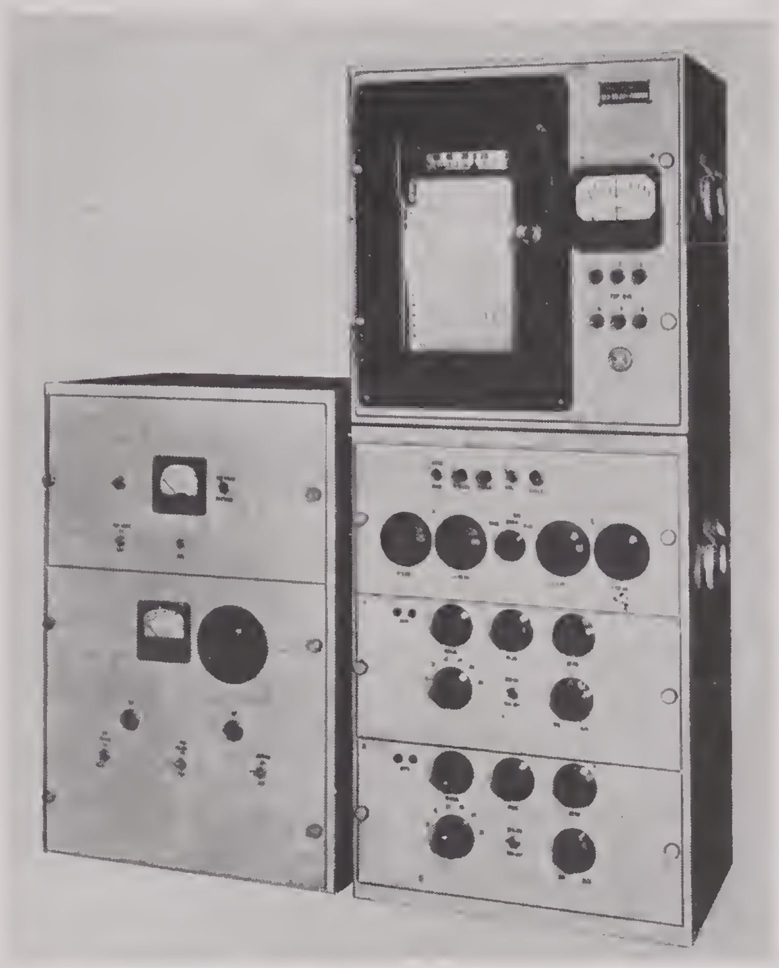


FIGURE 21. Electrical equipment cabinets for practice attack meter.

Practice Attack Meter

The practice attack meter is a system of devices designed to determine the accuracy of surface-vessel crews in carrying out practice antisubmarine attacks. The system includes a double channel pressure gradient hydrophone, amplifying and recording equipment, subcaliber depth charges which produce almost uniform explosive pressures, a release mechanism to discharge the projectiles, and a calculating chart for translating the recorder ordinates to bearing and range. In operation, the hydrophone, on the bridge of a submarine, picks up an impulse from the explosion of the special depth charge dropped by a practicing surface ship at the center of a hypothetical barrage. The resulting electrical pulse is amplified and recorded, registering the bearing and the range of the point of explosion. The system has a range sensitivity suitable for distances up to 1,000 ft, with an accuracy of reading, indicated by standard deviations, of 9 per cent in range and 7 degrees in bearing. The system was developed by BTL at the request of Division 6.

9.11 DESCRIPTION OF EQUIPMENT

The system comprises the following five components.

1. A double channel pressure gradient hydrophone.
2. An amplifying and recording system with power supply (in three units).
3. Subcaliber depth charges which produce, as nearly as possible, uniform explosive pressures.
4. A release mechanism to discharge the projectiles.
5. A calculating chart for translating the recorder ordinates to bearing and range.

The hydrophone is mounted on the bridge structure of the submarine and connected to the electric equipment within the submarine. The other items are used on the surface ship which works with this submarine.

PROJECTILE

The projectile consists of a steel tube weighted at the head and fitted with a flaring wooden tail. Within the tube is mounted the firing mechanism. Water pressure acting on a copper bellows compresses it and at the proper pressure the contact is closed. Current is furnished by a flashlight cell. The electrically fired explosive charge is mounted in a jack outside the wooden tail.

It was decided to adopt a design having a terminal rate of fall of approximately 6 fps, comparable to that of the standard 300-lb depth charge. Experience shows that in actual training operations hypothetical conditions must be set up. For routine operations it is not considered desirable to operate the submarine below some rather shallow depth, generally with the keel 90 ft below the surface. Yet for purposes of the training problem the submarine is assumed to be at some greater depth, generally from 100 to 600 ft. Hence some correction will be necessary for the short falling time of the projectile in training operations, as well as for other variables involved. These variables would include effects of turbulence, wake, and variations of depth at which firing occurs.

The depth at which the explosive charge should fire is dictated by several factors. It should be sufficiently deep so that the sound wave will be unaffected by the wake of the surface vessel. It should be above the wake of the submarine although the relative importance of the latter is unknown. In order to afford protection, explosion should occur above the hydrophone and periscopes. Accordingly the firing mechanism is set to operate at a pressure corresponding to a depth of 40 ft. Figure 22 shows, to scale, the location of the submarine, surface vessel, and charge explosion.

The explosive used is P.E.T.N., a Hercules Powder Company explosive similar to Tetryl. The explosive charge as developed consists of a 0.259-caliber bronze shell mounted on a coaxial plug. The assembly contains an electric ignition fuse, primer, and a charge of 1.35 g of P.E.T.N.

Loading and Release Mechanism

The projectiles and the explosive charges were to be shipped separately, and to arm the projectile it was necessary only to insert the plug of the charge in the jack of the projectile. To insure safety in this operation as well as a uniform method of dropping the projectile, a combination loading and firing assembly was designed which provides a safety loading chamber and means for electrically releasing the projectiles overside. A preliminary design was also worked out for a magazine-type release in which, after loading in the safety chamber, the projectiles would be stacked in a magazine ready to be released one at a time as required.

Hydrophone

In selecting a hydrophone design which would be suitable for use in this system it was necessary to satisfy several requirements:

1. Approximation to true cosine directivity pattern.
2. Frequency range.
3. Ruggedness.
4. Response.

The entire operation of the system depends on the directivity pattern of the hydrophone, which should be two cosine patterns with their principal acoustic axes at right angles.

The practice attack meter must function positively on the explosive pulse originating anywhere within the intended range and at the same time avoid false operation on interfering disturbances. There are two principal sources of such interference. At frequencies above 16,000 c, normal operation of QC systems must be expected to produce high-intensity disturbances. In the low-frequency region, water noise, including turbulence around the hydrophone, and ship noise predominate. To exclude these disturbances a band-pass filter is employed, the bandwidth ranging from 500 to 16,000 c. This bandwidth is adequate to retain the asymmetrical form of the pulse sufficiently undistorted to avoid ambiguity. Margin against false operation is assured by choice of a sufficiently powerful explosive charge combined with a relatively low response in the hydrophone, which covers most of this range with reasonable uniformity. Inasmuch as the type of rectifier circuit adopted has in effect a response which falls off 6 db per octave, the lower part of the hydrophone frequency range is of principal importance.

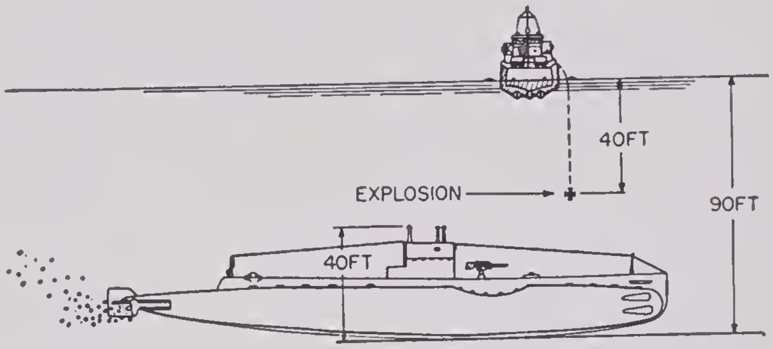


Figure 22. Location of submarine, surface vessel, and charge explosion.

Without impairing its acoustical performance, the hydrophone must be sufficiently rugged to withstand continual operation on board the submarine. This is a severe requirement when it is considered that it must withstand not only motion through the water but also the effects of breaking waves during diving and surfacing.

The requirement of response is lenient because of the high acoustic pressure developed by the exploding charge. In the frequency band below 50,000 c the pressure 16 ft away is

7×10^6 dynes per square centimeter for the 1.35 g P.E.T.N. charge.

The first hydrophone, which was unsatisfactory, consisted of two standard pressure gradient instruments in a water-filled Lucite housing. The next model[2] included two inertia operated assemblies within a single spherical shell. The units used are the same as those in the bone conduction receiver of the Orthotechnic audiphone.[3] The chief advantage of the inertia type of instrument is that it eliminates the necessity of diaphragms or other means of applying pressures from the acoustic wave to the active elements. The shell is made of aluminum, $2\frac{1}{16}$ in. in diameter, with a wall thickness of $\frac{3}{16}$ in. It resonates at 13,000 c, which is the upper limit of usefulness of the hydrophone.[4, 5] The lower limit is 600 c.

During experiments it was found that moving the hydrophone through the water at certain speeds would induce transverse vibrations of the head of the hydrophone with respect to the stand. The remedy was to support the sphere about its equator with a ring, which in turn is attached to the support with a cage-like structure (see Figure 23).

The entire support with the hydrophone in place has a transverse resonant frequency of the order of 10 c, thus forming a low-pass filter which protects the hydrophone from ship vibrations.

ELECTRICAL SYSTEM

Three cabinets contain the electrical equipment. In Figure 21, the top cabinet at the right holds the recorder. The cabinet below it has the control circuit at the top below which are the *A* and *B* amplifier and detector panels. (*A* and *B* refer to the two hydrophone units.) The left cabinet contains the regulated power supply at the top and the converter circuit below.

9.12 PRINCIPLE OF OPERATION

CIRCUIT DESCRIPTION

The operation of the electrical system is explained with reference to the simplified circuit diagram, Figure 24. The pulse from an exploding charge is received at the hydrophone, and

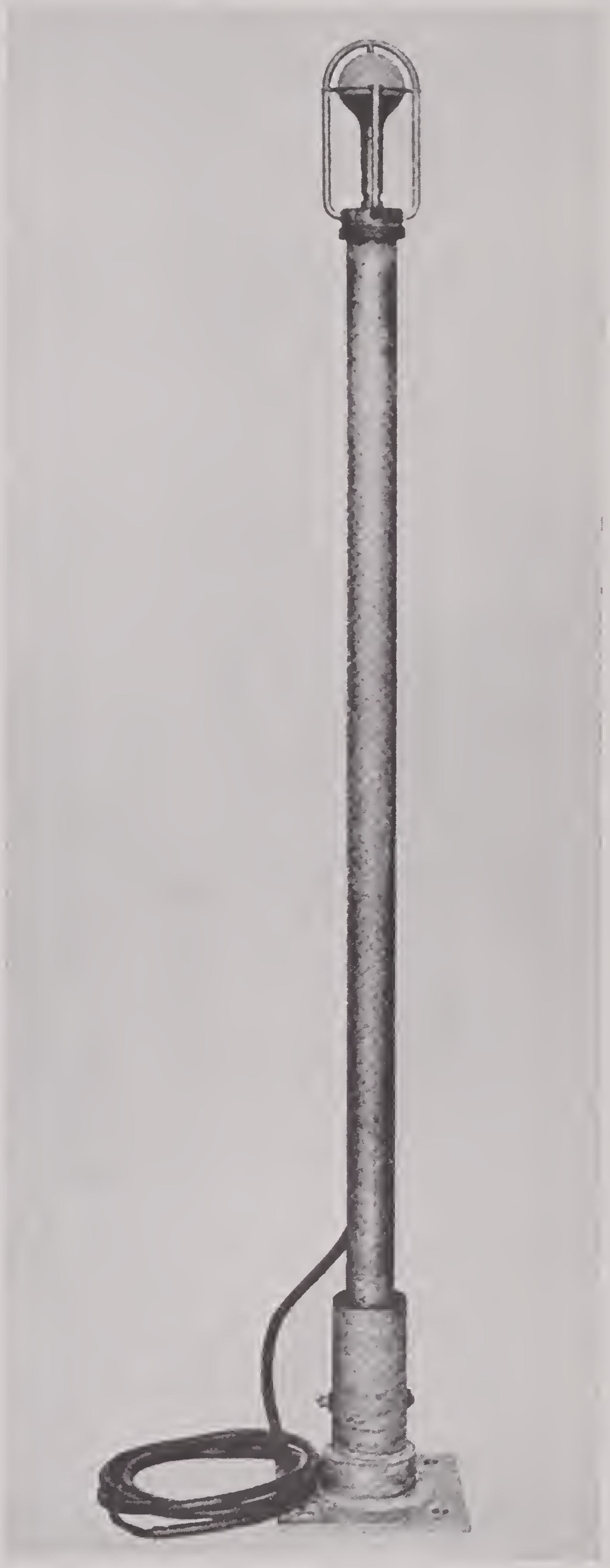


FIGURE 23. Hydrophone on stand.

the outputs of the two elements *A* and *B* are fed through separate attenuators for adjustment of range and for balance. Since the performance of the two channels is similar, the operation of the *A* channel only will be considered.

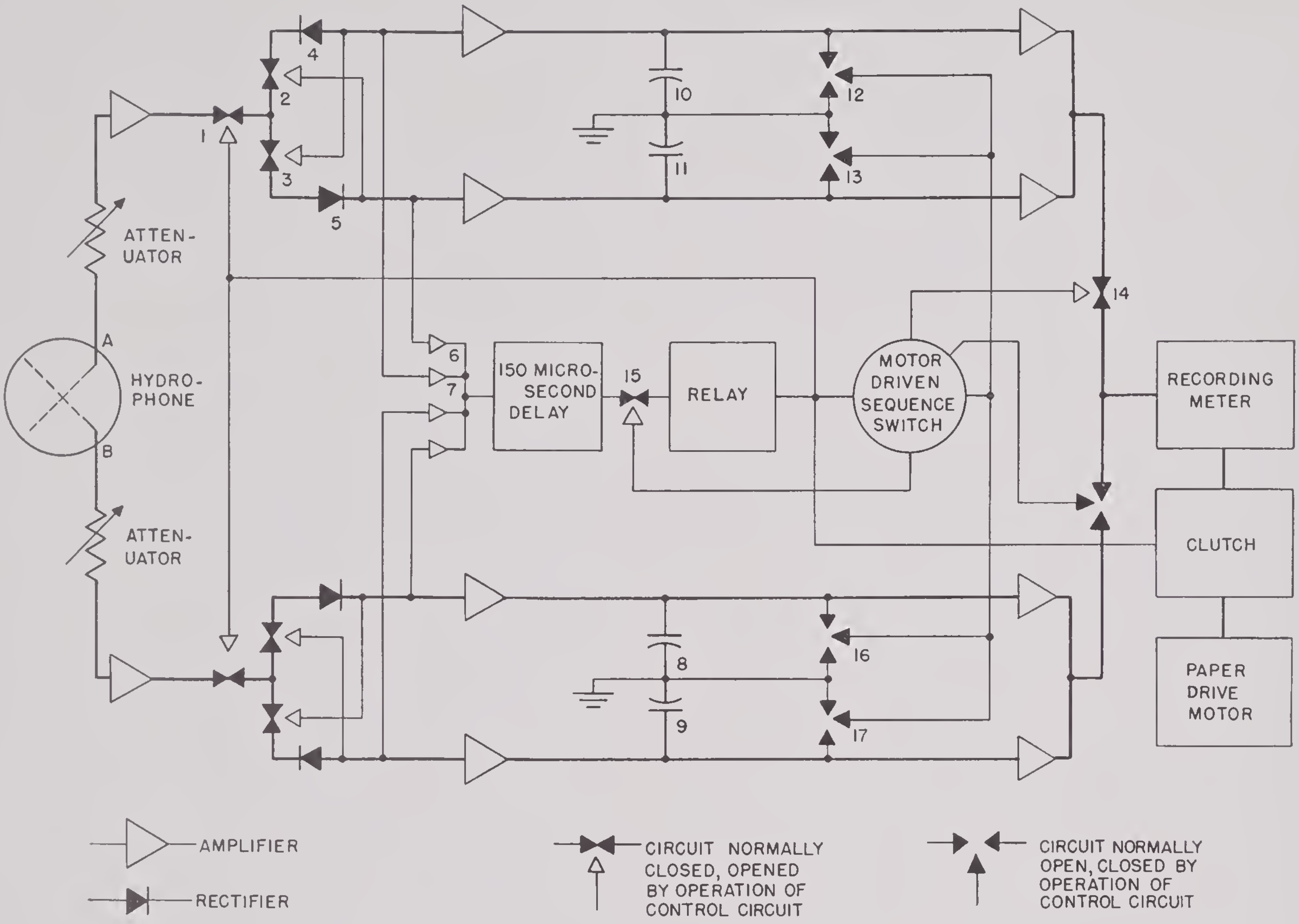

4
2
3
5
1
ATTEN-UATOR
A
HYDRO-PHONE
B
ATTEN-UATOR
10
11
12
13
14
6
7
150 MICRO-SECOND DELAY
15
RELAY
MOTOR DRIVEN SEQUENCE SWITCH
RECORDING METER
CLUTCH
PAPER DRIVE MOTOR
8
9
16
17
AMPLIFIER
RECTIFIER
CIRCUIT NORMALLY CLOSED, OPENED BY OPERATION OF CONTROL CIRCUIT
CIRCUIT NORMALLY OPEN, CLOSED BY OPERATION OF CONTROL CIRCUIT

FIGURE 24. Practice attack meter—simplified circuit diagram.

The pulse is amplified and fed to rectifiers 4 and 5. If the explosive pulse is received on the forward (positive) lobe of the *A* hydrophone element, the electric pulse will be positive and will be rectified by rectifier 4. The output of this rectifier acts immediately to open contact 3, so that the succeeding negative portion of the signal will not pass to rectifier 5. The output of rectifier 4 is amplified and charges condenser 10 to a voltage proportional to the magnitude of the pulse.

Had the pulse been received on the rear lobe of element *A* the electric pulse would have been negative. It would have been passed by rectifier 5, disconnecting rectifier 4 at contact 2, and condenser 11 would have received the charge. Outputs from both rectifiers are amplified at 6 and 7 and fed through the 150-μsec delay network to operate the relay. This initiates a number of operations. First contact 1 is opened, disconnecting the hydrophone from the rectifiers. This is important, since any pulse reaching the hydrophone more than 150 μsec (the time taken for sound to travel 8.5 in. in water) later than the initial pulse will be ignored. Thus echoes of the explosion from the water surface or from parts of the submarine cannot introduce errors in the readings. At the same time the relay actuates a clutch in the recorder which starts the paper moving and starts a motor-driven sequence switch which takes 8 sec to make a complete revolution. Initially the recording meter is connected to condensers 10 and 11 through their isolation amplifiers and reads the voltage to which one of these is charged, a positive reading if 10 is charged, negative if 11 is charged. After 2 sec the meter is disconnected at contact 14 and connected to the amplifiers

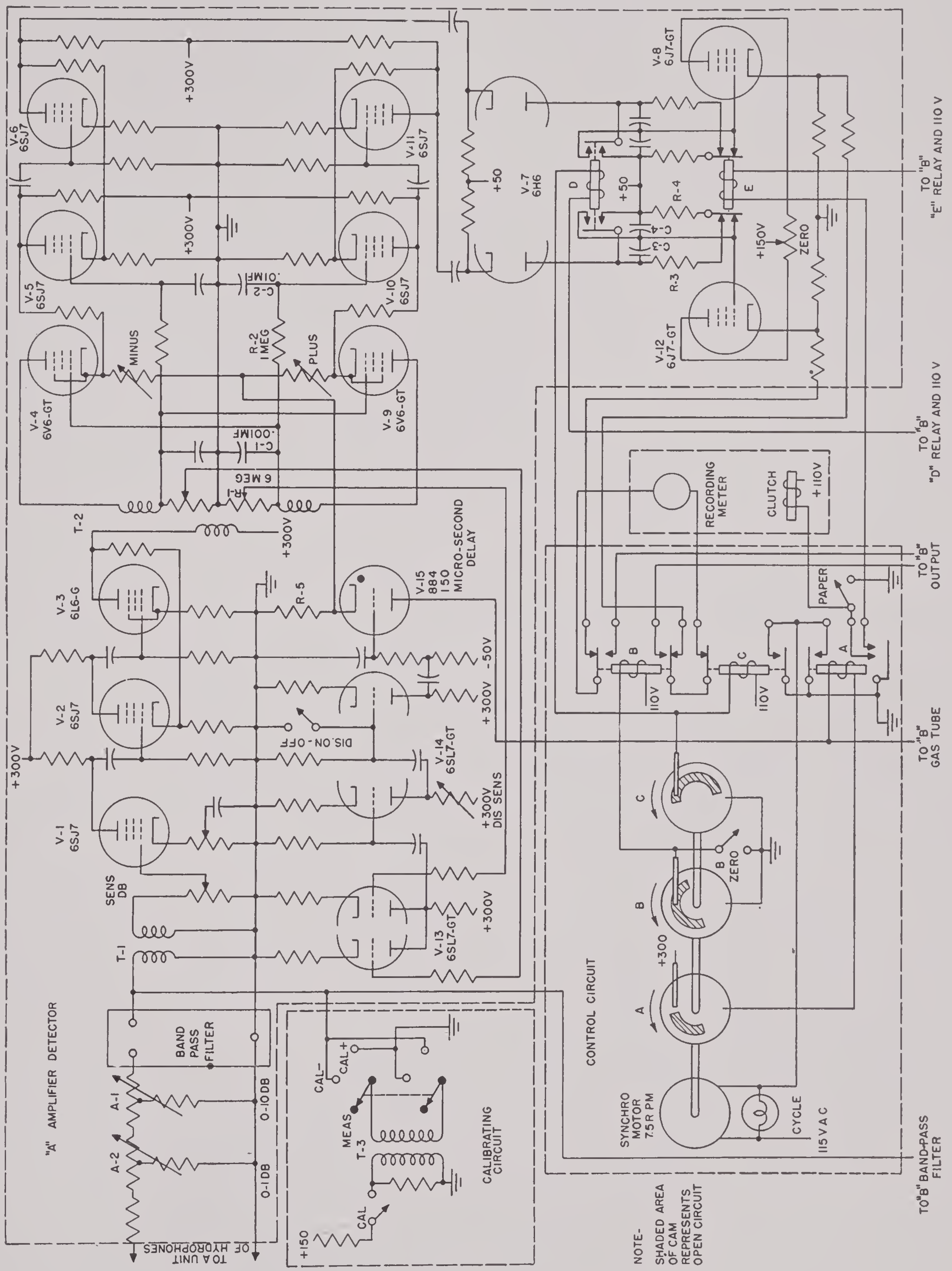

V-6
6SJ7
V-11
6SJ7
+300V
V-5
6SJ7
V-10
6SJ7
C-2
.01MF
V-7
6H6
+50
V-8
6J7-GT
D
E
R-4
C-4
C-3
R-3
+150V
ZERO
V-12
6J7-GT
TO "B"
"E" RELAY AND 110 V
V-4
6V6-GT
MINUS
R-2
1MEG
PLUS
V-9
6V6-GT
C-1
.001MF
R-1
6 MEG
TO "B"
"D" RELAY AND 110 V
RECORDING
METER
CLUTCH
+110V
T-2
+300V
V-3
6L6-G
R-5
V-15
884
150
MICRO-SECOND
DELAY
TO "B"
OUTPUT
PAPER
V-2
6SJ7
-50V
+300V
DIS.ON-OFF
B
110V
C
110V
A
TO "B"
GAS TUBE
+300V
V-14
6SL7-GT
+300V
DIS SENS
V-1
6SJ7
C
SENS
DB
B
ZERO
B
+300V
V-13
6SL7-GT
+300
T-1
A
CONTROL CIRCUIT
"A" AMPLIFIER DETECTOR
BAND
PASS
FILTER
CAL-
CAL+
A-1
MEAS
T-3
0-10DB
A-2
0-1DB
CALIBRATING
CIRCUIT
SYNCHRO
MOTOR
7.5RPM
CYCLE
115VAC
CAL
+150
TO A UNIT
OF HYDROPHONES
NOTE-
SHADED AREA
OF CAM
REPRESENTS
OPEN CIRCUIT
TO "B" BAND PASS
FILTER

FIGURE 25. Practice attack meter—system schematic.

following condensers 8 and 9. These were charged from the *B* hydrophone element in a fashion similar to that described for *A*. After being connected to the *B* channel for 2 sec the meter is disconnected and the condensers in both channels are discharged by the closing of contacts 12, 13, 16, and 17 for 2 sec. After 2 more sec the sequence switch opens contact 15 momentarily, releasing the relay, and the cycle is complete. The equipment is in the stand-by condition with the paper in the recorder stopped and is ready to receive another pulse whenever it may arrive (see Figure 25 for system schematic). A detailed description of the electric circuit will be found in the bibliography.[6]

Calibration

Overall calibration of the system is done by means of test charges located at a known distance on the submarine. Tables have been prepared showing expected readings for various switch settings. After calibration the system is

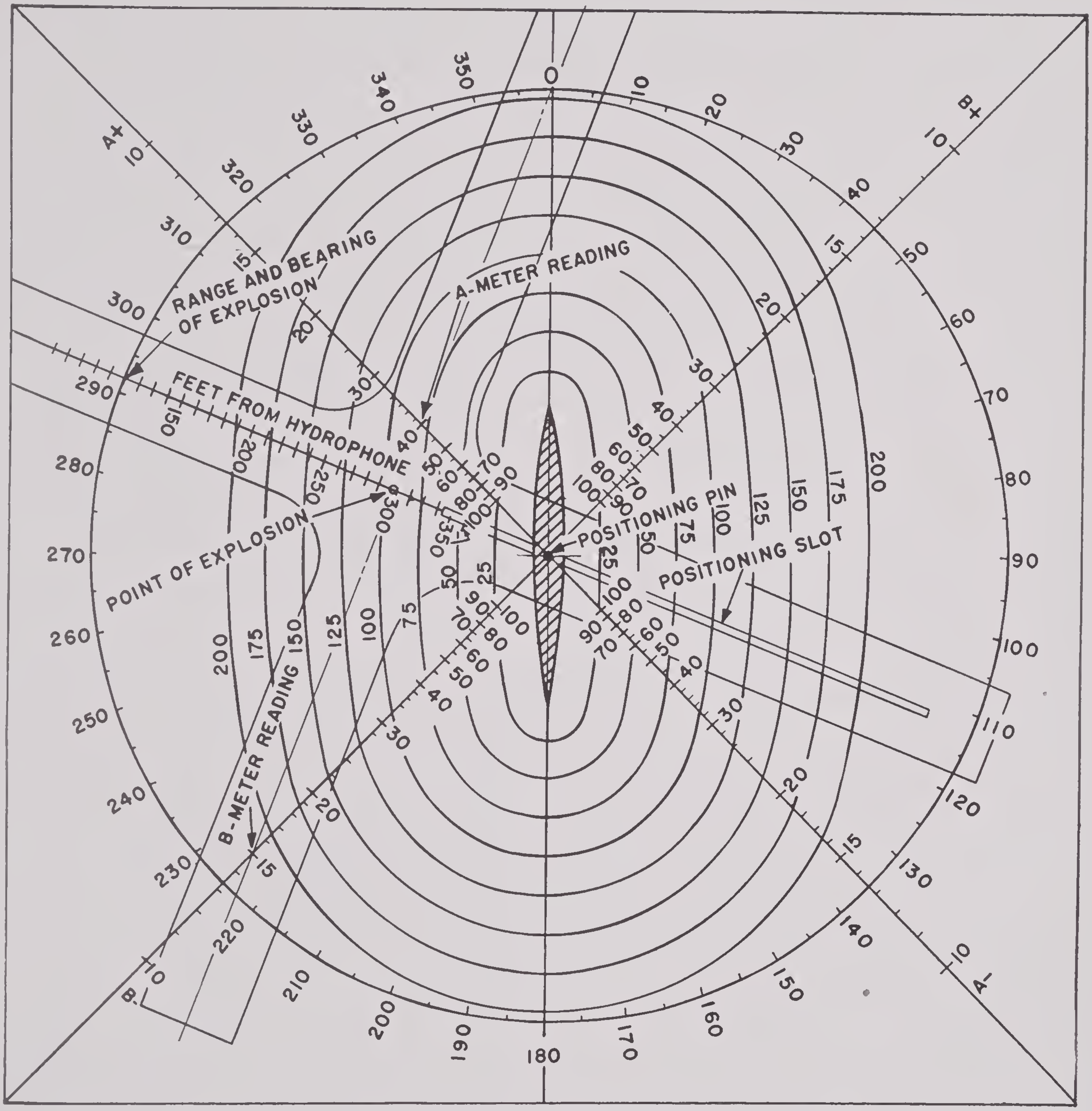

A+
B+
A−
B−
RANGE AND BEARING OF EXPLOSION
FEET FROM HYDROPHONE
A-METER READING
B-METER READING
POSITIONING PIN
POSITIONING SLOT
POINT OF EXPLOSION
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
330
340
350

Figure 26. Calculating chart.

ready for use, the only precaution being that the sensitivity switch should be set for the range desired. The maximum range, 200 to 1,000 ft, is obtained by the 0-db setting. Each 6-db reduction in the sensitivity divides the range figures by 2, the calculating chart having been plotted on the basis of 12-db reduction, or 50 to 250 ft. Since the cam cycle is 8 sec, for two explosions closer together than about 8 sec only the first will be recorded.

9.13 CALCULATING CHART

It has been shown that the response of a unit of the hydrophone to a charge fired on its axis is inversely proportional to the distance. For a charge not on either axis, and with certain assumptions, range and bearing may be calculated as follows:

$$R = \frac{5{,}200}{\sqrt{(D_A + 4)^2 + (D_B + 4)^2}},$$

$$\theta = 45^\circ + \tan^{-1} \frac{D_A + 4}{D_B + 4},$$

where R is the range in feet,

D_A and D_B are the meter deflections,

θ is the bearing in degrees with respect to the ship, assuming clockwise angles as positive.

To eliminate computation except in a few cases, the calculating chart shown in Figure 26 has been prepared. A positioning pin obtrudes through a hole at the center of the chart and a transparent cross-shaped slider is supplied with a slot which slides along the pin. Two crossed scales labeled $A+$, $A-$ and $B+$, $B-$ correspond to the meter deflections. The drawing shows the position of the slider for a recorder reading of $A+ = 40$ and $B- = 15$. At the center of the slider a hole permits drawing a small circle for the location of the explosion. From the circular outside scale this is seen to be at a bearing of 292 degrees. The range from the hydrophone, located at the pin, read on the slider scale where it crosses the circular outside scale, is 109 ft. Contour lines drawn around the hull show that the explosion was about 90 ft from the nearest point on the hull. The meter deflection scale is shown down to only 10 as a compromise between size and accuracy of the chart and because inherent inaccuracies cause greater percentage errors at the lower scale readings. The minimum distance that can be read from the chart is 35.5 to 50 ft, whereas the maximum distance is 262 to 372 ft, depending on the bearing. Where only one reading is below 10 the location can be estimated by the chart, since the low reading does not greatly affect the distance. For both readings below 10 the formulas given can be used.

9.14 TESTS OF THE SYSTEM[7]

Trials were made to determine the performance of the practice attack meter and to discover the explosive effects of various charges. The results of some tests were erratic because of the influence of wake. This situation will not be encountered in actual practice where explosion will take place 40 ft below the surface. Surface reflections, due mainly to the longer delay of 500 μsec in the operation of the disabling circuits of the detectors, also contributed to observed discrepancies.

Calibration tests were made to determine the accuracy of the system. Results show that the true system error distribution has a standard deviation between 7 and 9 per cent for range. For bearing the deviation is between 3.5 and 7 degrees. Some factors causing variations between tests are the trajectories and firing times of the projectiles, the influence of wakes and other transmission irregularities in the medium. Among the more important differences in the overall calibration is the technique of calibration itself. Assumptions are involved such as maintenance, throughout a run, of known and straight courses at strictly uniform speeds for both surface vessel and submarine. These assumptions are not, of course, strictly valid. Furthermore, the determination of the theoretically correct firing points involves a measure of judgment and approximation. The errors introduced thereby are unquestionably more critical for bearing than for range and may well be comparable in magnitude to the true errors of the system itself.

9.15 RECOMMENDATIONS AND CONCLUSIONS

Recommended Mechanical Changes.

1. Because the various dials on the electric equipment used to adjust different parts of the circuit were too easily disturbed from their proper setting, it seems desirable to move those which are infrequently used, such as the hydrophone sensitivity adjustments, inside the panel, and to provide the others with screwdriver slots rather than knobs.
2. The visual meter wired in series with the recording meter was seldom if ever used and should be removed.
3. The electrical calibrating circuit should be improved to eliminate false calibration readings caused by erratic functioning of the calibrating switch.
4. The projectile release mechanism, which was far from foolproof, might be replaced by a magazine type of device.
5. A more comprehensive plotting board, with all horizontal distance scales in yards to conform to Navy practice, seems desirable.

Training Problems. In the application of the practice attack meter to training problems, the two important facts given must be considered.

1. The information developed in practice attacks should be obtained quickly and in such form that it will be clear to the trainee.
2. A visual representation is necessary. This would show the actual relation between the point of explosion and the location of the target submarine.

Conclusions. Trial of the practice attack meter under actual training conditions indicated that it was practicable for the purpose intended and was a material improvement over methods then in use to determine the results of practice attacks.

It is directly applicable to other types of training attack, such as by the ahead-thrown projectile. Equipment of the subcaliber projectile used in this system with a charge fired at the proper depth would permit using a single projectile representing the center of the barrage. It would give positive indication of accuracy of aim even though a direct hit is not scored.

The meter may also be of value in appraisal of new and experimental attack or conning methods and systems by providing rapidly a quantitative picture of performance.

Chapter 10

PRACTICE TARGET EQUIPMENT

Because of the extravagance of using submarines in echo-ranging training maneuvers, various types of practice targets were developed as substitutes. An important economy was thus achieved and the training program was accelerated.

Practice targets, consisting essentially of echo repeaters, are mounted on stationary buoys, on the keels of target vessels, or are towed underwater, so that sonar operators can ping at them and receive echoes closely simulating those returned by a submarine, as well as genuine reverberation. Since real reverberation and echoes are much more difficult to distinguish than artificially generated reverberation and echoes, practice targets provide a more advanced type of training than shore-based attack teachers. They do not, however, provide wake echoes, which sonarmen must learn to distinguish from the true submarine echo. Towed targets may return a very faint wake echo, but nothing comparable to that of a submarine wake. It is therefore advisable that some part of echo-ranging maneuvers include practice with an actual submarine target.[a]

Although the series of targets designed for training purposes were of different types, they were all based on the same general principles. In the summary which follows, the general principles are outlined first, followed by a description of the individual targets, BR-1, RR-1, KR-1, SR-2, and SR-5, developed at the University of California Division of War Research laboratory [UCDWR] at San Diego. Echo repeaters developed at the Harvard Underwater Sound Laboratory [HUSL] were used only for calibration and testing. In the event of further development work, however, they could also be applied in the training field. The Harvard echo repeaters are described in Division 6, Volume 18, Chapter 6.[b]

10.1 GENERAL PRINCIPLES

When an underwater sound beam from an attacking ship strikes a submarine, part of the energy from that sound beam is reflected and may be picked up by the sound gear of the attacking ship. A target that is to substitute for a submarine must simulate its reflection in intensity, directional effects, and frequency changes.

In order to meet these requirements, the practice target must have a hydrophone (receiver transducer) with uniform response about its normal axis, an amplifier to raise the level of the signal received, and a projector (transmitter transducer) with uniform response about its normal axis. Ideally the transducers should be so designed and mounted that their response drops to zero when the attacking vessel approaches a position directly over the target. The mechanical design of the target should also incorporate the type of streamlining and trim necessary to simulate, when towed, the motion of a submarine.

10.2 TRANSDUCERS FOR PRACTICE TARGETS

Both hydrophone and projector transducers used in the San Diego practice targets consist of 45-degree x-cut Rochelle salt crystal stacks. The hydrophone picks up energy from the ping sent out by the sonar practice team and converts it into an electric signal. This signal is amplified, converted back into sound energy at the projector, and re-radiated into the water, thus producing a strong artificial echo. The artificial echo has many of the fundamental characteristics of a true submarine echo. For example, its loudness is proportional to the loudness of the transmitted signal. In the case of towed targets, the doppler effect is also present, since the frequency of the repeated echo is altered in accordance with the motion of the target just as an actual submarine echo would be.

These effects are obtained, however, only if the water temperature remains in the neighborhood of 75 F. Above or below this temperature, x-cut Rochelle salt crystals suffer a marked drop in sensitivity. In the Atlantic, which has wide temperature variations, the San Diego practice targets were not so effective as in the Pacific. Because of this serious limitation in the sensitivity of Rochelle salt crystals, the use of ADP crystals in practice targets might well be explored.

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[a] To mark the position of a submarine when submerged during testing and training exercises, a marker buoy was developed to be towed by the submarine. To extend its range of visibility, a smoke signal was later added to this marker buoy. These devices are described in Division 6, Volume 18, Chapter 11.

[b] Practice targets and other training devices used with magnetic airborne detection equipment are discussed in Division 6, Volume 5, Chapter 7.

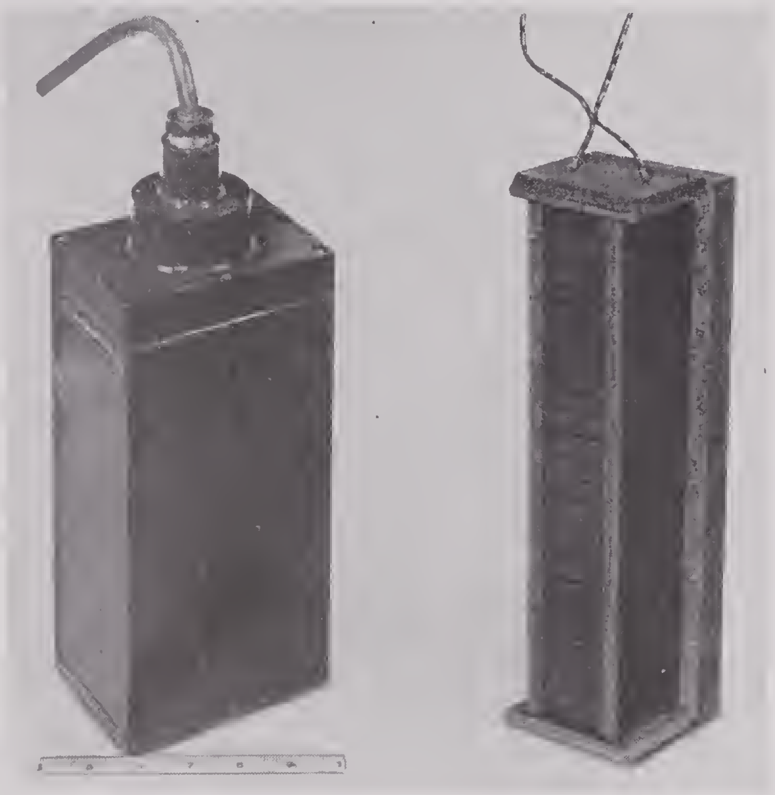


Figure 1. BD-1 transducer.

Acoustical coupling between the projector and the hydrophone, if pronounced, would cause the repeater to "howl." To prevent this, the transducers are carefully insulated from the metal parts adjacent to them, and are mounted as far apart as other considerations permit. In addition, they are so oriented that each is in the low-sensitivity area of the other's directivity pattern.

Transducer Directivity Patterns

The construction of the crystal stacks leads to directivity patterns which are fairly uniform opposite the transducer face but which begin to shrink approximately 12 degrees from the plane through the face. (The transducer face, which is the free surface of the crystal stack, is usually indicated on the outside of the housing by a name plate.) Since the transducers are generally mounted with faces normal to the beam of the towing vessel, the drop in sensitivity means that the effective target strength decreases when the attacking vessel is pinging from an angle of 12 degrees or less to either side of the target's bow or stern. These directional characteristics correspond closely to the actual dependence of a submarine's target strength on aspect angle. The regions of low sensitivity, being adjacent to one another because the transducers are mounted in the same plane, not only minimize acoustical coupling but also serve to reduce undesirable pickup of the towing vessel's screw noise.

The two chief types of transducer used in the sonar practice target are the BD-1, illustrated in Figure 1, and the CD-1, illustrated in Figure 2. The frequency response and directivity patterns for these two types of transducer are shown in Figure 3.

In the BD-1, when it acts as a projector, the drop in sensitivity mentioned above is pronounced. The box-like metal housing produces a blind spot of 30- to 40-db attenuation along the 90- to 270-degree axis, as shown in Figure 3A. As a receiver, however, the BD-1 transducer directivity pattern does not show this blind area along the 90- to 270-degree axis, but does have two lesser blind areas 10 to 12 degrees on either side of that axis (see Figure 3A).

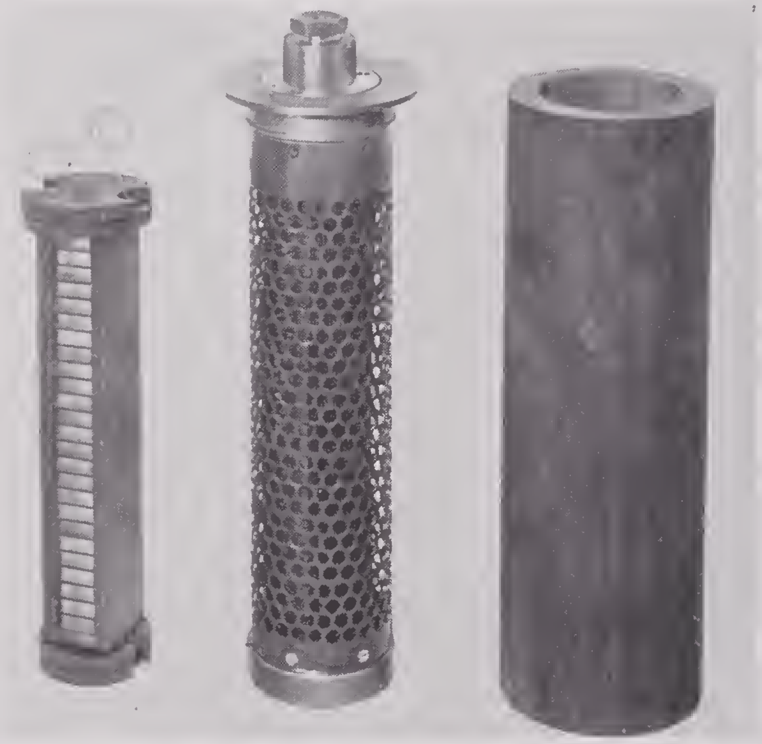


Figure 2. CD-1 transducer.

The CD-1 type of transducer, on the other hand, has a directivity pattern, both as transmitter and as receiver, in which the weakened sensitivity areas are much less pronounced and occur at about 25° to 30° angles from the plane of the crystal faces (see Figure 3B). These characteristics are common also to the CG-1 and CJ-1 transducers.

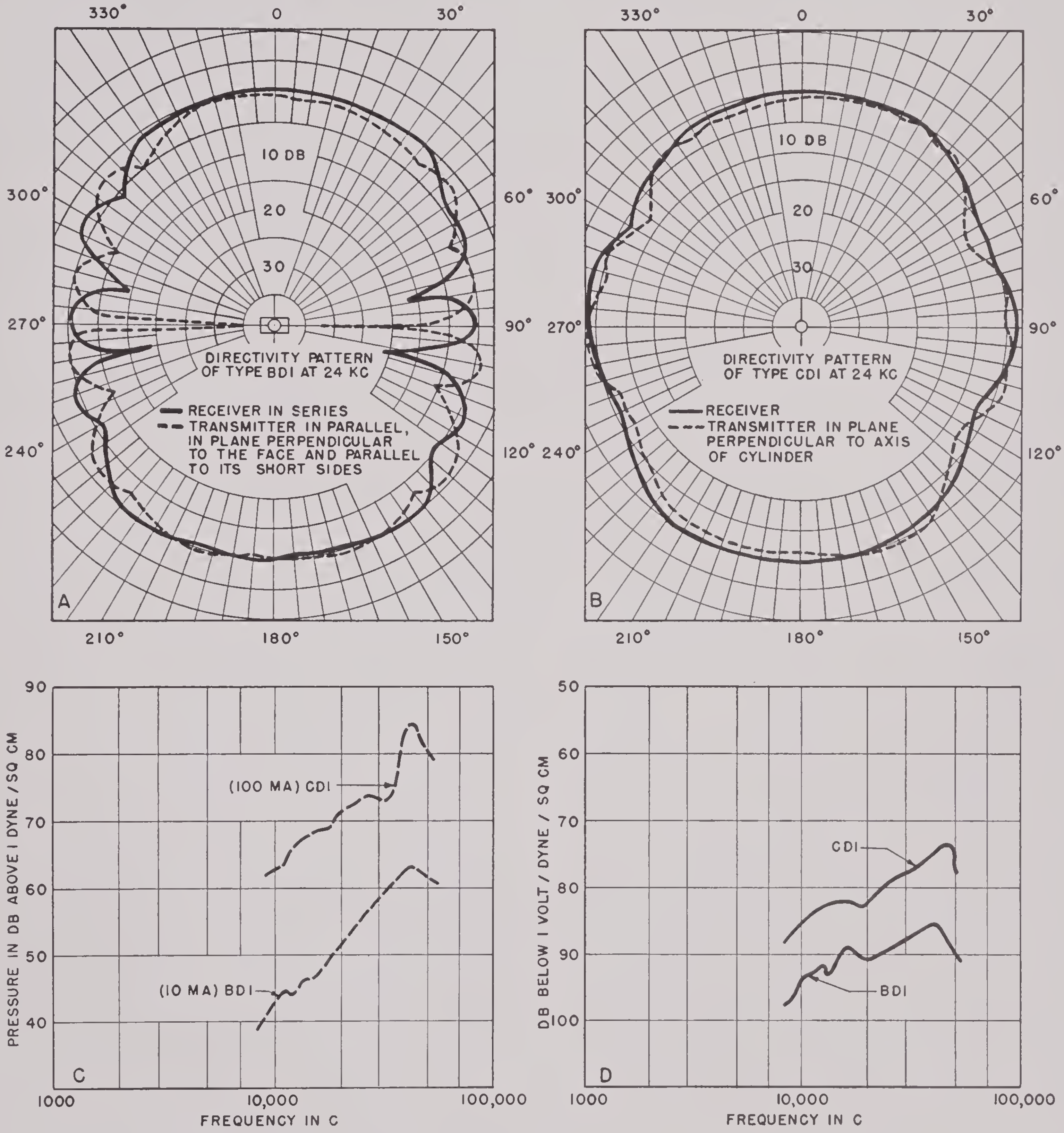


FIGURE 3. Directivity and response curves of BD-1 and CD-1 transducers.

The BD-1 Transducer. BD-1 transducers serve as hydrophone and projector in both the RR-1 raft-suspended and the KR-1 keel-mounted targets. Each transducer consists of a double bank of 24 Rochelle salt crystals, each 1x1½x¼ in., insulated by corprene pads and spacers and immersed in vapor-free castor oil. When installed in the target, the two banks of crystals in the hydrophone are connected in series so that they are in phase. Those in the projector are connected in parallel, 180 degrees out of phase. Operating the transducers in this way reduces acoustical coupling to a minimum, permitting maximum gain settings for the amplifier.

CD-1, CG-1, and CJ-1 Transducers. CD-1, CG-1, and CJ-1 transducers are used as hydrophones and projectors in the SR-2, SR-5, and BR-1 practice targets. They are all alike, except that CG-1 has mounting brackets of a different size, and CJ-1, which superseded CD-1, has a ¼-in. tire-stock rubber sleeve. These transducers make use of a single stack of 26 Rochelle salt crystals, each ¼x¾x1½ in., connected electrically by strips of German silver foil and immersed in vapor-free castor oil. The perforated metal cylinder which serves as a protective housing in this model (see Figure 2) has about 50 per cent open area and offers good acoustical transparency between crystal faces and the cylindrical rubber outer casing.

TABLE 1. Comparison of amplifier specifications.

	Amplifiers for use with A/S practice targets					
	S1	S1-AB	S2-AB	S3-AB	U2-AB*	S5-AB
Frequency range (kc)	17–26	16–26	16–26	16–26	16–26	16–26
Input impedance (ohms)	100	125	125	125	125	125
Output impedance (ohms)	100	125	125	125	125	125
Overall gain (db)	90	108	114	114	116	114
Total watts (125-ohm load)	6 @ 100 ohms	9.2	8.7	8.7	8.7	8.7
Watts less than 5% dist.		4.0	4.0	4.0	4.0	4.0
B volts (full load)	290	275	295	295	280	295
Type of B power supply	Mallory VP552 Vibrapack	Mallory VP552 Vibrapack	Mallory VP552 Vibrapack	Mallory VP552 Vibrapack	A. T. & R. Co. Type 12RSA Inverter	Mallory VP552 Vibrapack
Total storage battery drain (amp)	9 @ 6 v	5.8 @ 6 v	6.5 @ 6 v	6.5 @ 6 v	13 @ 12 v	7 @ 6 v
Used on A/S PT's	RR-1 KR-1	KR-1 RR-1 BR-1	RR-1 KR-1	BR-1	SR-2	SR-5

* AC voltage at U2-AB control cabinet, 115 to 117.

10.3 AMPLIFIERS FOR PRACTICE TARGETS

Since practice targets are generally operated from small boats, buoys, or rafts lacking an a-c power source, a battery-operated power supply is needed with an amplifier suitable for use with this power.

Because the sensitivity of the transducer crystals varies with temperature, dropping off noticeably above or below 75 F, the amplifiers are designed to have approximately twice the gain required for satisfactory operation at 70 F.

Table 1 gives the specifications for the various amplifiers used with sonar practice targets, which are all similar in layout and operation. Figure 4 is a schematic diagram of a typical target amplifier, the S3-AB.

The frequencies used by the attacking ships fall in the range 16 to 26 kc. The target receiver picks up any signal in this range and feeds it into the amplifier input. In operation, heterogeneous signals may reach the target receiver as the result of reflections, screw noise, and reverberation. If the signal that is reemitted is to represent the echo from a submarine, it is necessary to eliminate these unwanted frequencies before amplification takes place. This is accomplished by a band-pass filter that couple stage 1 and 2 in the amplifier.

Figure 5 shows the band-pass filter, which consists of two inductively coupled resonant circuits. This filter has been adjusted to give the pass band shown in the figure as the overall amplifier frequency response. On either side of this pass band, signals are attenuated to such

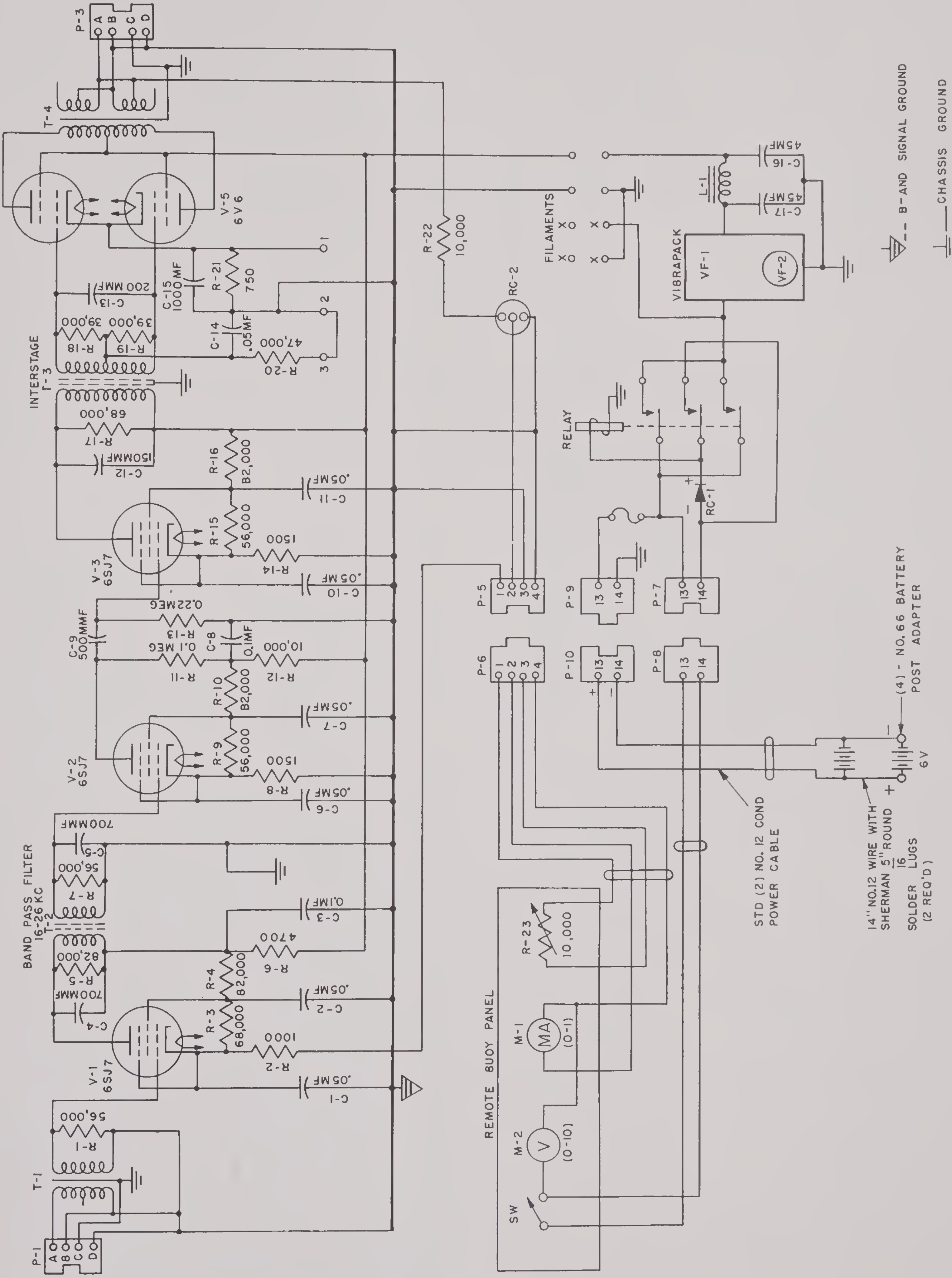
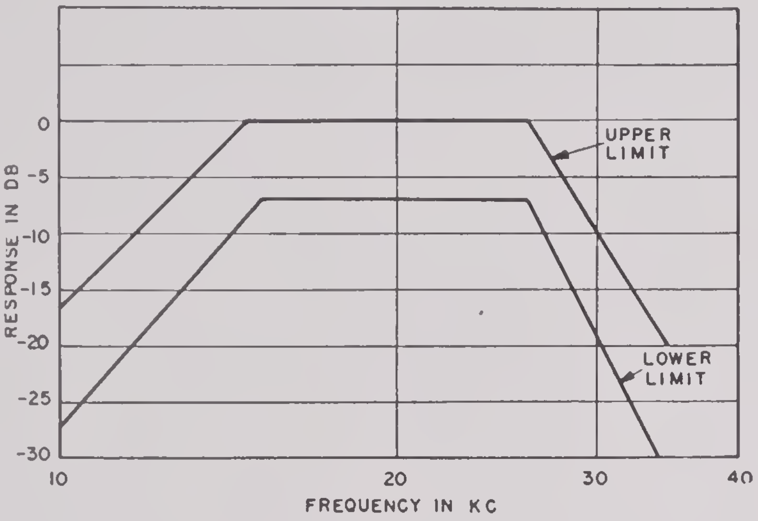

P-1
A B C D
T-1
R-1
56,000
V-1
6SJ7
C-1
.05MF
R-2
1000
R-3
68,000
R-4
82,000
C-2
.05MF
R-6
4700
C-3
0.1MF
C-4
700MMF
R-5
82,000
T-2
BAND PASS FILTER
16-26 KC
R-7
56,000
C-5
700MMF
V-2
6SJ7
C-6
.05MF
R-8
1500
R-9
56,000
C-7
.05MF
R-10
82,000
R-11
0.1 MEG
R-12
10,000
C-8
0.1MF
R-13
0.22MEG
C-9
500MMF
V-3
6SJ7
C-10
.05MF
R-14
1500
R-15
56,000
C-11
.05MF
R-16
82,000
C-12
150MMF
R-17
68,000
INTERSTAGE
T-3
R-18
39,000
R-19
39,000
C-13
200MMF
R-20
47,000
C-14
.05MF
C-15
1000MF
R-21
750
1
2
3
V-4
6V6
V-5
6V6
T-4
P-3
A B C D
R-22
10,000
RC-2
FILAMENTS
L-1
C-16
45MF
C-17
45MF
VIBRAPACK
VF-1
VF-2
RELAY
RC-1
P-5
1 2 3 4
P-6
1 2 3 4
P-9
13 14
P-10
13 14
P-7
13 14
P-8
13 14
REMOTE BUOY PANEL
R-23
10,000
M-1
MA
(0-1)
M-2
V
(0-10)
SW
STD (2) NO. 12 COND
POWER CABLE
14" NO.12 WIRE WITH
SHERMAN 5/16" ROUND
SOLDER LUGS
(2 REQ'D)
(4) - NO. 66 BATTERY
POST ADAPTER
6V
B-AND SIGNAL GROUND
CHASSIS GROUND

FIGURE 4. Schematic diagram of S3-AB target amplifier.

an extent that they do not appreciably affect the second stage of the amplifier.

The filter output is amplified, as shown in the schematic diagram (Figure 4), and applied to the power output tubes. These in turn are coupled to the projector transducer which projects the signal as a simulated submarine echo.

Since the band-pass filter provides a flat acoustical operating region from 16 to 26 kc, it can accommodate simultaneous signals from several sonar equipments operating at different frequencies within the band. Provided they operate at frequencies which do not overlap and cause mutual interference, several ships may ping at one time at the same target.



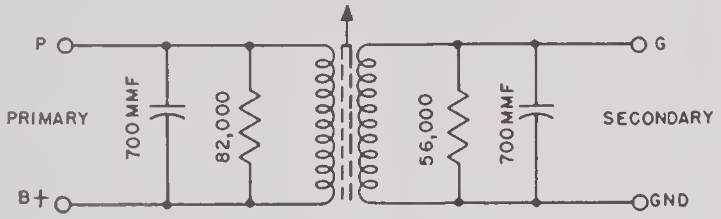


FIGURE 5. Band-pass filter for S3-AB amplifier.

The amplifier and power supply are mounted near the power source in all the targets except the SR-2. With the same exception, all have transducers fed through not more than 50 ft of cable. Each of the amplifiers, except the U2-AB in the SR-2, operates from a 6-volt storage battery connected to a Mallory Vibrapack, which develops 275 to 300 volts at 100 ma for the amplifier plate supply. In the SR-2 target, which is designed for towing on cables as long as 1,200 ft, the amplifiers and power supply are housed in the target body. To avoid too frequent opening of the target, which would be necessary if batteries were installed in it, an a-c operated amplifier was designed for this model. An inverter mounted in the towing vessel is used to develop the alternating current, which is fed to the power supply through the towing cable.

The amplifiers provided for the sonar practice targets appear to have given satisfactory service, but any future research or development on such targets should take into consideration the later amplifiers built for the 6- and 10-in. NAD beacons, discussed in Division 6, Volume 19.

Brief summaries of the various practice target models developed for use in sonar training exercises follow. Operational data may be obtained from the instruction manual covering the individual type of target (see bibliography).

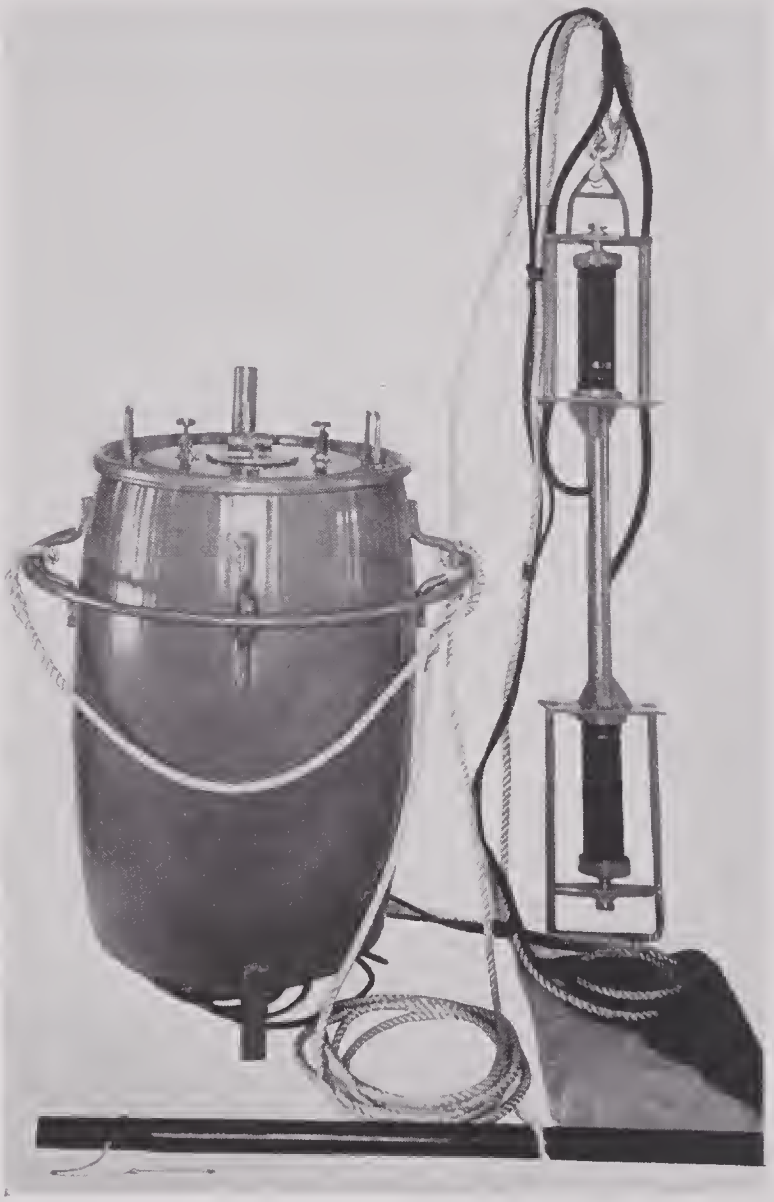


FIGURE 6. Practice target, model BR-1.

Practice Target Model BR-1

The model BR-1 practice target, developed by UCDWR at the request of the West Coast Sound School, is a stationary buoy-supported echo repeater for use in training sonar operators. Since this target does not provide doppler or range rate, it is used chiefly to drill individual sonarmen in the recognition of reverberation and echo signals. The essential components of the device are a hydrophone, a transmitting projector, an amplifier and a power supply. The hydrophone and projector are identical crystal transducers (type CG-1 or CJ-1). They are suspended by means of a manila rope at a depth of 27 ft from the bottom of a steel buoy, which houses the amplifier (model S1-AB or S3-AB), the power source and the control equipment. A glass covered panel above the amplifier carries the off-on switch, the gain control, a battery voltage meter, and a signal indicator meter. A glass window in the buoy top permits the operator to observe the meters, and control handles, extending up from the panel to valves in the buoy top, enable him to make necessary adjustments. A special jellied electrolyte is used in the battery power supply; the batteries, housed in the bottom of the buoy, help to provide proper trim.

The buoy is made from a seamless steel bilge barrel to which suitable fittings are attached. In the bottom of the barrel stuffing boxes provide entrance for the transducer cables and a mounting bracket supports the transducer assembly. Lifting rings make handling easy, and legs attached to the bottom of the buoy make it possible to stand the buoy on deck or dock without damaging the equipment. The amplifier is mounted inside the buoy near the top with a control panel above it.

Two 6-volt batteries are installed in the bottom of the buoy. Since the BR-1 is subject to considerable rolling and tipping, it is necessary to use batteries with jellied electrolyte which require special care in charging.[1, 2] After this buoy had seen service, it was also found necessary to add a gas-venting system, because storage batteries of the type used in the BR-1 generate hydrogen gas at all times, whether standing idle or under load, thus giving rise to a danger of explosion.[3] A further modification in later models was the addition of stronger transducer supports.[3a]

Two types of amplifier have been used with this target, the S1-AB and the S3-AB. The S3-AB, shown in the schematic diagram in Figure 4, is similar in operation to the S1-AB but has a somewhat higher gain and a higher B power supply voltage at the output terminal block (see Table 1). Detailed circuit analyses will be found in the appropriate instruction manuals.[1a, 2a]

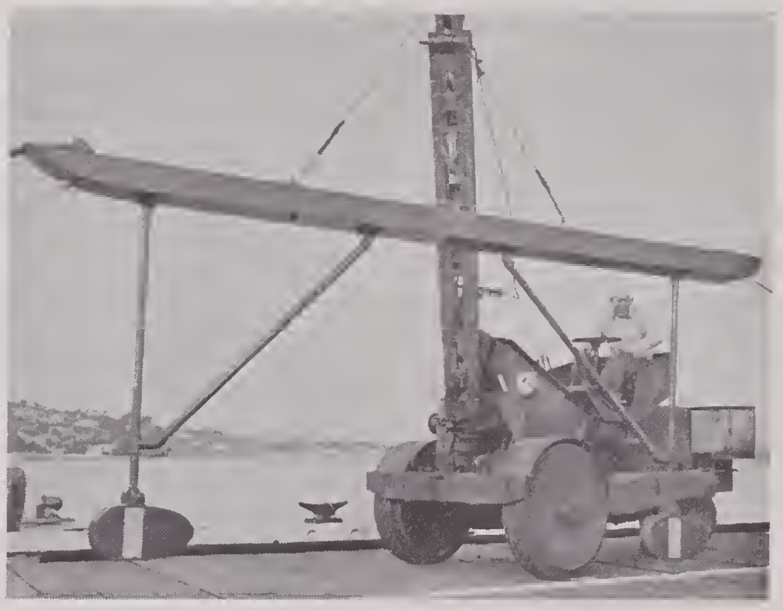


FIGURE 7. Practice target, model RR-1.

Practice Target Model RR-1

The model RR-1 practice target developed by UCDWR is a raft-type towed underwater echo repeater used in sonar maneuvers. Two BD-1 type transducers are suspended at a depth of 6 ft from a wooden raft or spar and spaced 10 ft apart to prevent acoustical coupling. A bandpass amplifier (S1, S1-AB, or S2-AB) and the power source (a 6-volt storage battery) are carried aboard the boat which tows the raft. The apparatus is designed to return echoes in the range of frequencies from 17 to 26 kc. By picking up and transmitting the screw noise of the towing vessel, this gear will also roughly simulate submarine propeller sounds.

The method of housing the transducers is illustrated in Figure 8. The transducer is inserted into the streamline socket from below and held in place by a bolted cover plate. A lining of ⅛-in. corprene insulates the transducer acoustically from the metal holder. Electric cable connections extend from the transducers through the supporting pipes, through a groove, and under a cleat on the top side of the wooden float, and thence to the towing boat. A free length of 35 ft of cable is provided between this cleat and the terminating amplifier connectors.

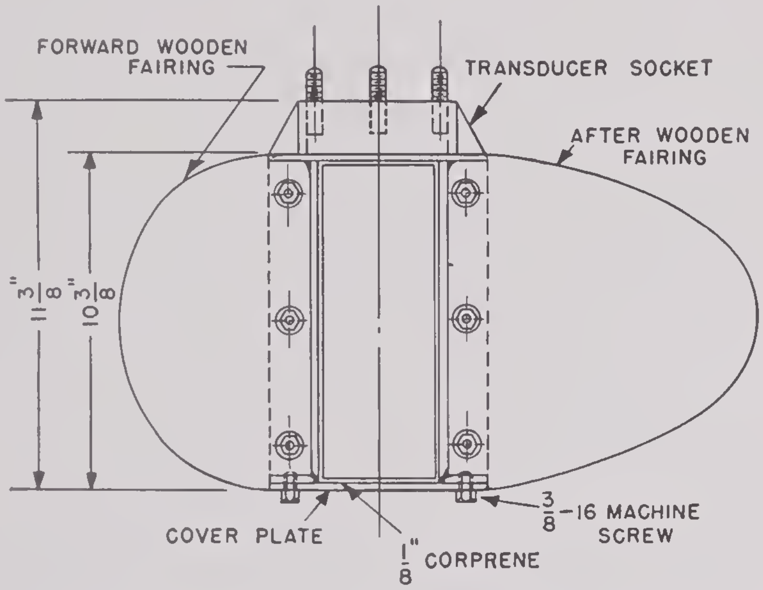


FIGURE 8. Streamline transducer housing in target model RR-1.

Table 1 gives the gain and power output ratings of the three types of amplifiers suitable for use with this model.

With the RR-1 practice target, it is also possible to simulate roughly the screw noise of a submarine. The propeller noise of the towing craft is picked up and projected with the echo. This is accomplished by connecting the two transducers so that the forward one is the hydrophone. The raft is towed further forward than usual and at one side of the stern of the towing craft so that the hydrophone is nearly abeam of the propeller. Since the towing boat is moving slowly, its propeller speed is roughly that of a submarine. Towing the target abeam of the propeller places the latter opposite a lobe of the hydrophone directivity pattern, rather than in a "dead" area.

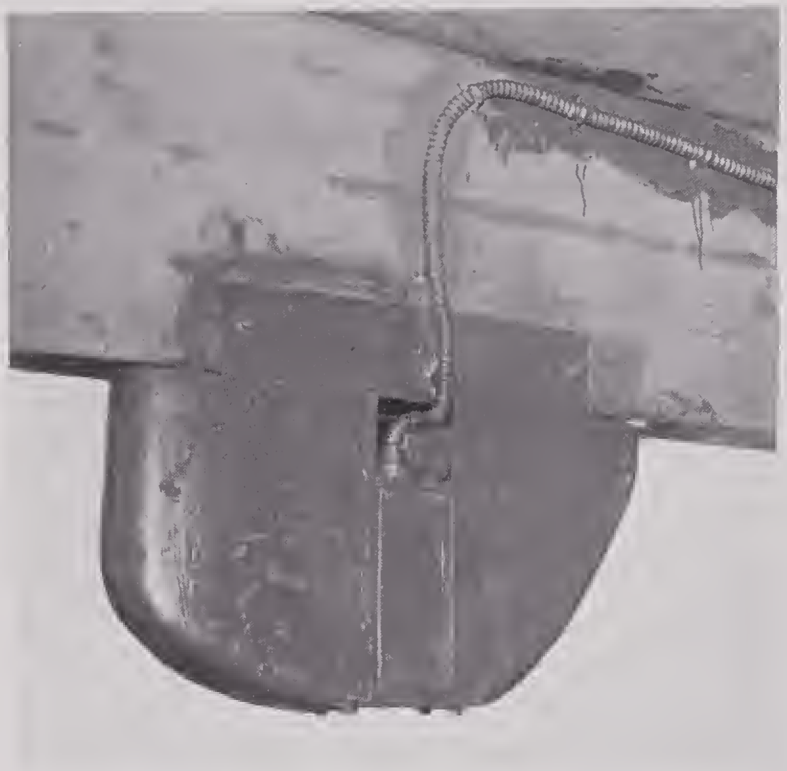


FIGURE 9. Practice target, model KR-1 (only one transducer installation shown).

Practice Target Model KR-1

The model KR-1 practice target is a keel-mounted echo-repeater developed by UCDWR for use in sonar team training maneuvers. It consists of two model BD-1 Rochelle salt crystal transducers (a hydrophone and a projector) coupled to a 16- to 26-kc band-pass amplifier (model S1-AB) with a maximum voltage gain of 106 db. The hydrophone and the projector are attached to the keel of the target boat near the bow and stern respectively. The transducer cables are carried into the ship through watertight stuffiing boxes in the hull. The amplifier and power supply can be located at any convenient point on board the target boat. When an underwater sound "ping" from the practice ship strikes the hydrophone, a voltage appears across its output terminals. This voltage is amplified and then fed into the projector, which transmits its output to the water as a simulated echo.

10.4 COMPARATIVE EVALUATION OF THE KR-1 AND RR-1 TARGETS

Although considerably more efficient in operation than the RR-1, the KR-1 is limited in application. It requires a custom-built mechanical structure to mount the transducers on the keel of the target boat, as the keel dimensions of different boats vary greatly. Furthermore, the target boat must be put in dry dock in order to mount the transducers and to install the necessary watertight stuffing boxes that carry the transducer cables through the ship's hull. The KR-1 thus involves the use of a particular vessel; the RR-1 can be used with any available towing craft. In order to match the transducer depth of the RR-1, the KR-1 must be mounted on a vessel of at least 6-ft draft.

In general, however, once the installation is completed, the KR-1 is superior to the RR-1 for sound training purposes. Since the transducers are permanently attached to the keel of the target vessel, there is no towing or handling problem, and no danger of entangling the transducer cables in the propeller of the towing vessel, as sometimes happens with the RR-1. The spacing between the transducers is limited only by the keel length of the target vessel, which usually allows a greater transducer separation than the 10-ft spacing used on the RR-1. This greater separation reduces acoustical coupling and so permits use of higher amplifier gain levels without danger of feedback.

Moreover, training can be carried on in any type of weather in which the practice ship can operate. This is not true of operation with the RR-1, which is a difficult unit to handle in heavy seas. The target ship equipped with KR-1 can proceed to the operating area at any desired speed. The RR-1, on the other hand, is a low-speed towing unit, and considerable time is lost if any appreciable distance must be covered to reach the operating area.

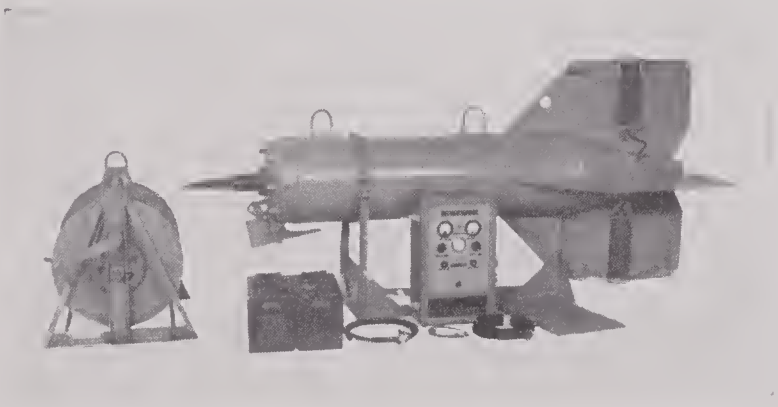


Figure 10. Practice target, model SR-2.

Practice Target Model SR-2

The model SR-2 practice target, developed by UCDWR, is a 4-ft long towed underwater echo repeater used in sonar maneuvers. The type U2-AB amplifier and power supply are housed in the body of the target and the two transducers (CD-1, CG-1, or CJ-1) are mounted in the vertical tail fins; a remote control cabinet is carried aboard the towing vessel. The target can be towed on as much as 1,200 ft of cable at speeds which permit simulated attack runs in deep water.

The Model SR-2 practice target is shown with its accessory equipment in Figure 10. Welded to the iron body of the target, which is 14 in. in diameter and 4 ft long, is a conical tail section 20½ in. long, with four radial fins. The towing cable is secured to the center of the target head through a flexible, watertight, neoprene nose. Proper trim is obtained by placing ballast in the forward end of the body and on the lower vertical fin. Fully assembled, the target weighs about 340 lb and has a small positive buoyancy above that required to support the tow cable.

The transducers used in the SR-2 practice target are the CD-1, CG-1, or CJ-1, described earlier in this chapter. Figure 11 shows how the transducers are attached to the vertical fins of the target. To prevent acoustical feedback through the metal, the metal cases of the transducers are insulated from the target body.

An amplifier that will operate satisfactorily with the SR-2 practice target must deliver considerable power to drive the projector. This necessitates the charging of the batteries after each day's operation (8 to 10 hours). For convenience, the batteries are therefore carried aboard the towing vessel, with a 12-volt inverter to supply alternating current to the type U2-AB amplifier. Table 1 gives specifications to which this amplifier has been built.

The power for the U2-AB amplifier is supplied through the tow cable, an electric oil-well logging cable which has a central insulated 7-strand conductor and which is attached to a winch for handling purposes. This same cable functions as the line for the remote gain con-

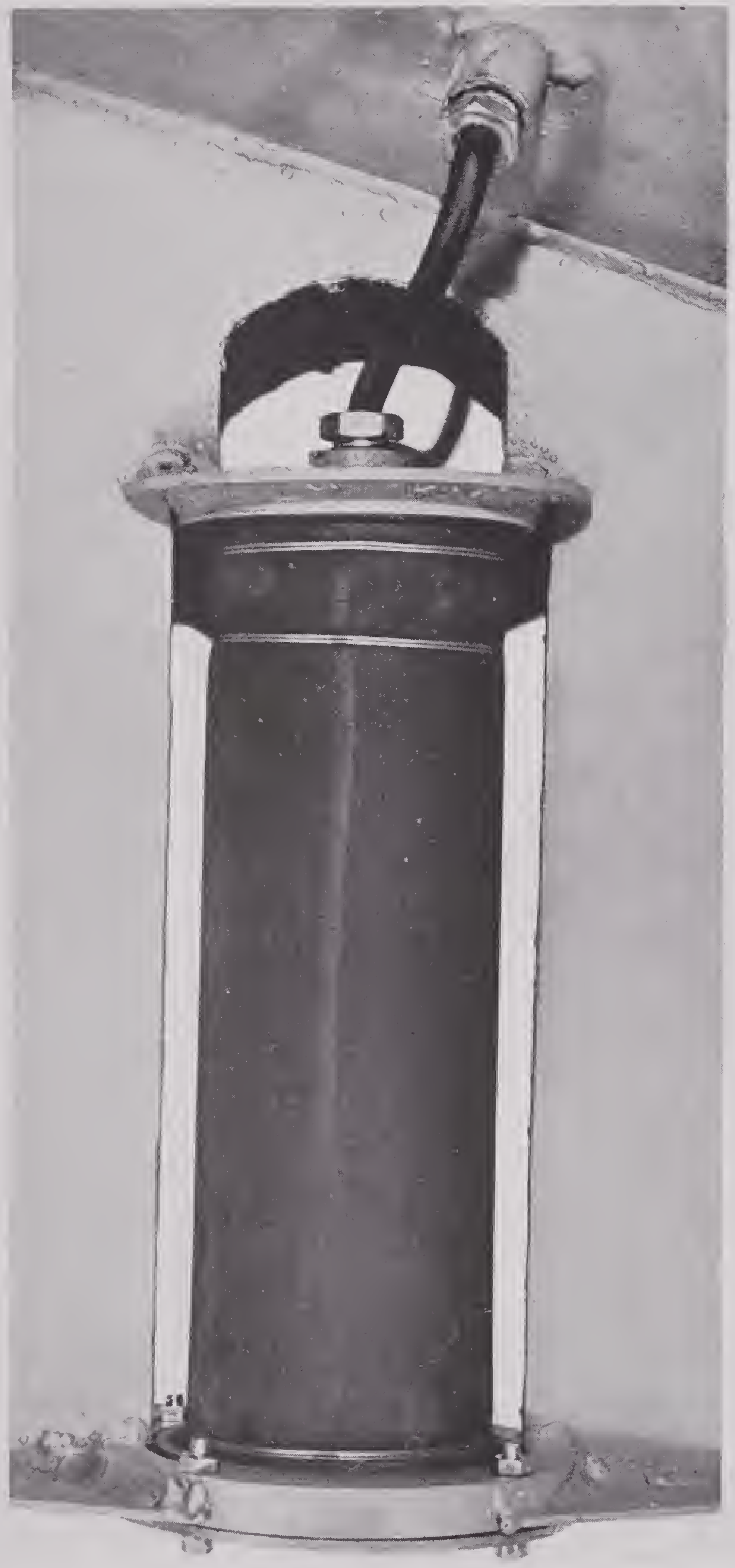


FIGURE 11. Transducer mounting in target model SR-2.

trol, the remote signal indicator, and the depth gauge indicator. Figure 12 shows how the various units of the equipment are connected, and Figure 13 is a schematic wiring diagram of the U2-AB amplifier and power supply. A detailed analysis of the circuits will be found in the instruction manual prepared for use with the SR-2 target.[4]

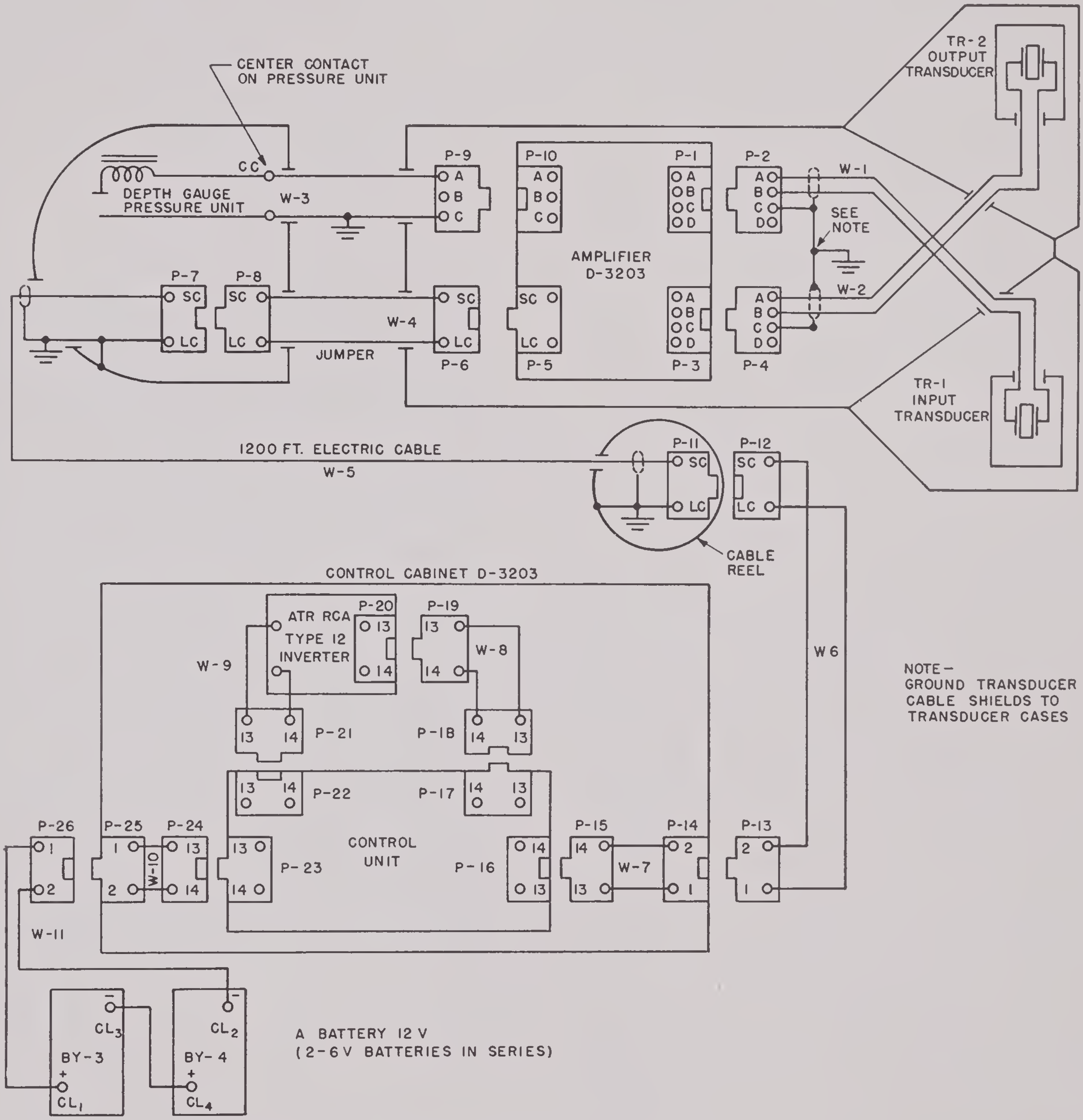

CENTER CONTACT ON PRESSURE UNIT
TR-2 OUTPUT TRANSDUCER
CC
DEPTH GAUGE PRESSURE UNIT
W-3
P-9
A
B
C
P-10
A
B
C
P-1
A
B
C
D
P-2
A
B
C
D
W-1
SEE NOTE
AMPLIFIER D-3203
P-7
SC
LC
P-8
SC
LC
W-4
JUMPER
SC
LC
P-6
SC
LC
P-5
A
B
C
D
P-3
A
B
C
D
P-4
W-2
TR-1 INPUT TRANSDUCER
1200 FT. ELECTRIC CABLE
W-5
P-11
SC
LC
P-12
SC
LC
CABLE REEL
CONTROL CABINET D-3203
ATR RCA TYPE 12 INVERTER
P-20
13
14
P-19
13
14
W-8
W-9
W6
13
14
P-21
P-18
14
13
NOTE — GROUND TRANSDUCER CABLE SHIELDS TO TRANSDUCER CASES
13
14
P-22
P-17
14
13
P-26
1
2
P-25
1
2
W-10
P-24
13
14
13
14
P-23
CONTROL UNIT
P-16
14
13
P-15
14
13
W-7
P-14
2
1
P-13
2
1
W-11
−
CL3
BY-3
+
CL1
−
CL2
BY-4
+
CL4
A BATTERY 12 V (2-6 V BATTERIES IN SERIES)

Figure 12. Interconnection diagram for target model SR-2.

The depth of the target can be measured by determining the pressure on the target caused by the head of sea water. An electric oil pressure gauge calibrated in feet of sea water is used for this purpose. The motor pressure unit of this device is installed in the head of the target, and the dial gauge is located in the remote control cabinet (Figure 14).

Since the only electric connection between the control cabinet and the target is through the tow cable, the depth indicator cannot be operated when the amplifier is in use. When

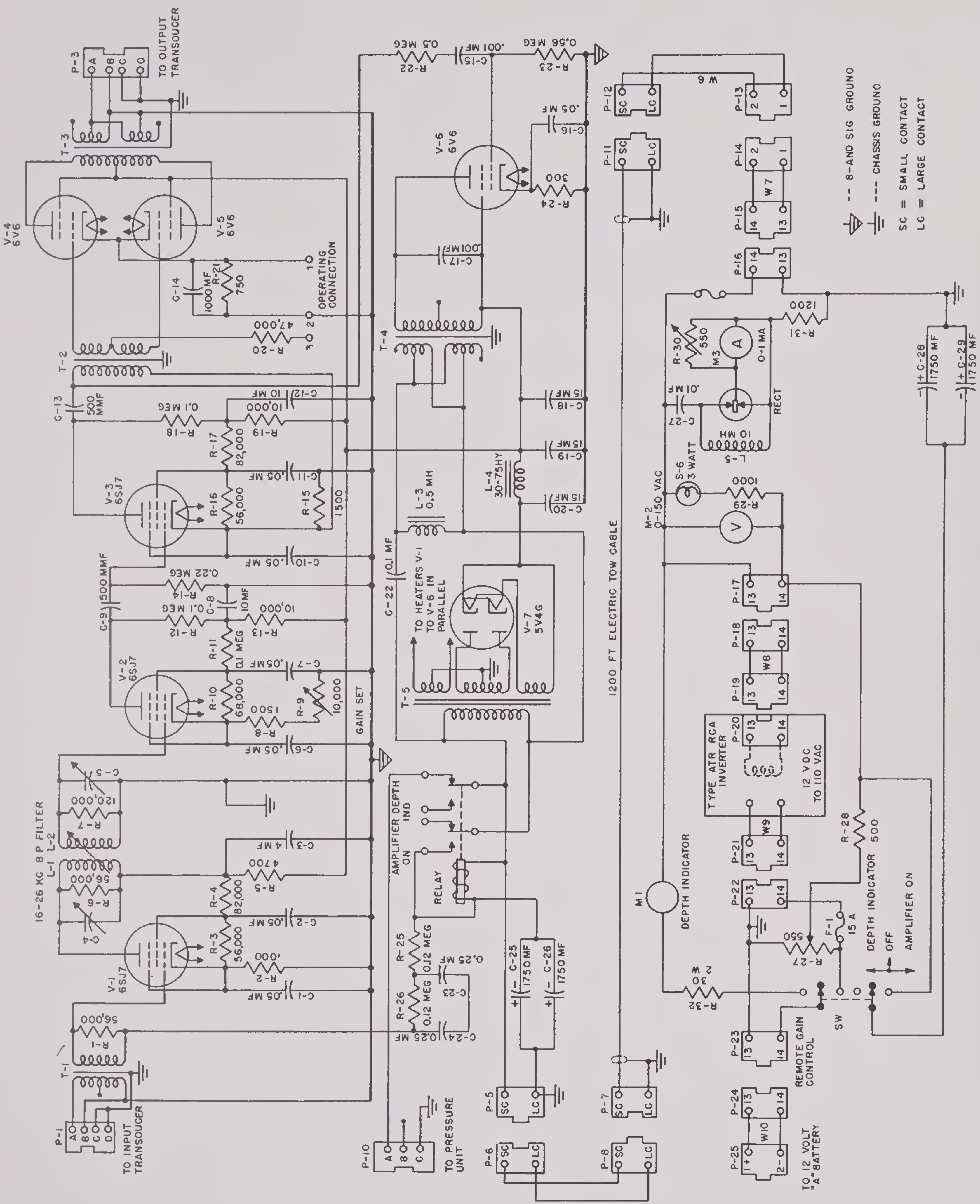

P-1
A B C D
TO INPUT TRANSDUCER
T-1
R-1 56,000
V-1 6SJ7
C-1 .05 MF
R-2 1000
R-3 56,000
C-2 .05 MF
R-4 82,000
R-5 4700
C-3 4 MF
C-4
R-6 56,000
L-1 L-2
16-26 KC 8 P FILTER
R-7 120,000
C-5
V-2 6SJ7
C-6 .05 MF
R-8 1500
R-9 10,000
GAIN SET
R-10 68,000
C-7 .05MF
R-11 0.1 MEG
R-12 0.1 MEG
C-8 10 MF
R-13 10,000
R-14 0.22 MEG
C-9 500 MMF
C-10 .05 MF
V-3 6SJ7
R-16 56,000
R-15 1500
C-11 .05 MF
R-17 82,000
R-18 0.1 MEG
R-19 10,000
C-12 10 MF
C-13 500 MMF
T-2
R-20 47,000
3 2 1
OPERATING CONNECTION
C-14 1000 MF
R-21 750
V-4 6V6
V-5 6V6
T-3
P-3
A B C D
TO OUTPUT TRANSDUCER
R-22 0.5 MEG
C-15 .001 MF
R-23 0.56 MEG
V-6 6V6
C-16 .05 MF
R-24 300
C-17 .001MF
T-4
C-18 15MF
C-19 15MF
L-4 30-75HY
C-20 15MF
L-3 0.5 MH
C-22 0.1 MF
TO HEATERS V-1 TO V-6 IN PARALLEL
V-7 5V4G
T-5
AMPLIFIER DEPTH IND
AMPLIFIER ON
RELAY
R-25 0.12 MEG
R-26 0.12 MEG
C-23 0.25 MF
C-24 0.25 MF
C-25 1750 MF
C-26 1750 MF
P-10
A B C
TO PRESSURE UNIT
P-5 SC LC
P-6 SC LC
P-7 SC LC
P-8 SC LC
W 4
1200 FT ELECTRIC TOW CABLE
P-11 SC LC
P-12 SC LC
W 6
P-13 2 1
P-14 2 1
W 7
P-15 14 13
P-16 14 13
R-31 1200
R-30 550
M3
A
0-1 MA
C-27 .01 MF
RECT
L-5 10 MH
S-6 3 WATT
M-2 0-150 VAC
R-29 1000
V
P-17 13 14
P-18 13 14
W8
P-19 13 14
P-20 13 14
TYPE ATR RCA INVERTER
12 VDC TO 110 VAC
P-21 13 14
W9
P-22 13 14
M I
DEPTH INDICATOR
R-28 500
R-27 550
F-1 15 A
DEPTH INDICATOR
OFF
AMPLIFIER ON
R-32 30 2 W
SW
P-23 13 14
REMOTE GAIN CONTROL
P-24 13 14
W10
P-25 1+ 2-
TO 12 VOLT "A" BATTERY
C-28 1750 MF
C-29 1750 MF
-- B-AND SIG GROUND
--- CHASSIS GROUND
SC = SMALL CONTACT
LC = LARGE CONTACT

FIGURE 13. Schematic diagram of U2-AB target amplifier.

the control switch (SW) is set at "depth indicator," no power is delivered to the inverter, and the a-c relay on the amplifier chassis opens to the depth indicator position. The 12-volt battery is then connected to the depth gauge circuit.

TOWING CHARACTERISTICS

The SR-2 model was designed for two specific purposes, to be towed with a head depressor on a 25- to 50-ft cable in shallow water such as harbors, and to be towed without the head depressor on an 800- to 1,200-ft cable in deep water.

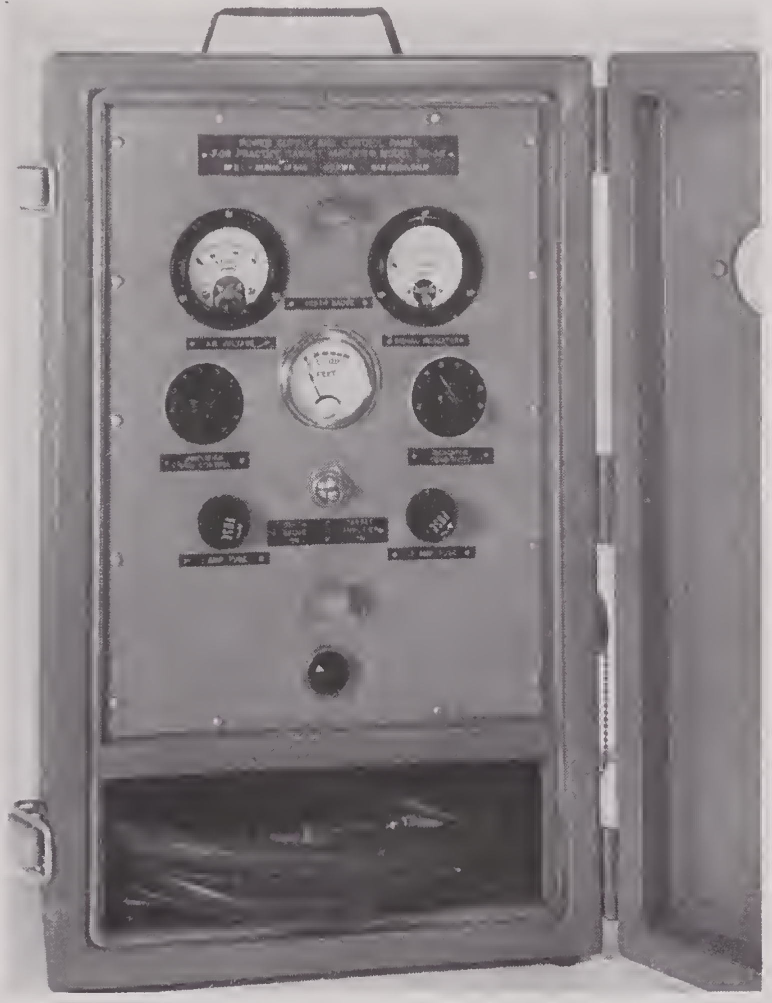


FIGURE 14. Remote control cabinet for target model SR-2.

In the first case the target is useful in the preliminary training of sonar operators aboard the attack ship. For this service the head depressor must be used in order to submerge the target to operating depth. A depressor angle of 15° is recommended, but any angle may be used which will give the desired submergence of the target. Care must be taken to prevent the target from striking submerged objects or the bottom.

In the second case the attack ship can pass over the towing cable and make simulated attack runs on the target. The greatest cable length that is consistent with operating conditions should be used for this purpose, 1,200 ft whenever possible. On these runs the attack ship must pass sufficiently far astern of the towing boat to clear the cable. Under normal conditions this distance is 300 ft. It is also important that the target depth be such that the attack ship will pass over it.

It should be noted that the addition of the head depressor (Figure 11) produces a marked change in the towing characteristics. When the head depressor is not used, the submersion of the target depends on the downward drag of the cable. At low speeds the tension on the cable is small and the resultant downward force is insufficient to submerge the target. At somewhat higher speeds the target submerges. The experimental data presented in Table 2 give the range of speeds for given cable lengths within which the target will be submerged.

TABLE 2. Approximate operating characteristics of model SR-2 without head depressor.

Cable length (ft)	Speed (knots)	Target depth (ft)
700	5	18
700	6	0
800	3½	47
800	4	41
800	5	33
800	6	27
800	7	0
900	3½	70
900	4	62
900	5	47
900	6	32
900	7	27½
900	7½	20
900	8	0
1,000	3½	92
1,000	4	86
1,000	5	68
1,000	6	57
1,000	7	0
1,100	3½	80
1,100	4	57
1,100	5	43
1,100	6	37
1,100	7	0

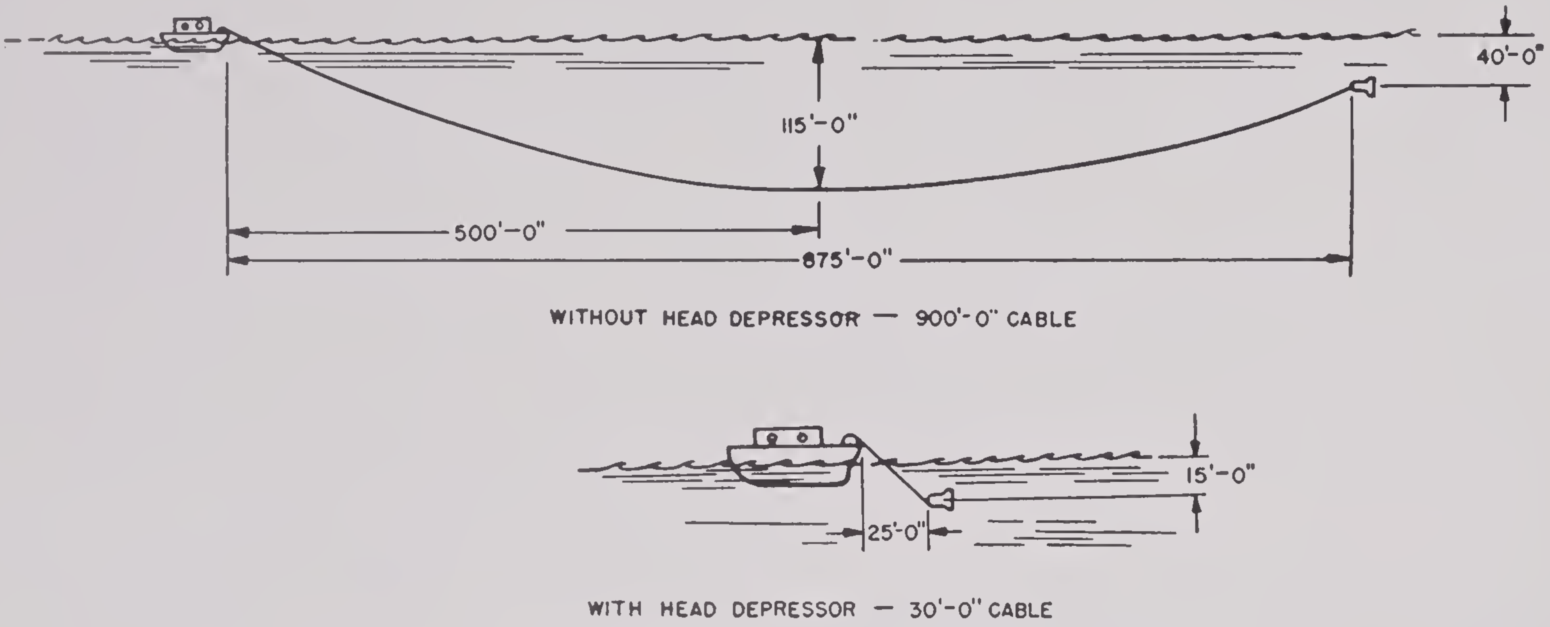

115'-0"
40'-0"
500'-0"
875'-0"
WITHOUT HEAD DEPRESSOR — 900'-0" CABLE
15'-0"
25'-0"
WITH HEAD DEPRESSOR — 30'-0" CABLE

FIGURE 15. Typical towing arrangements for target model SR-2.

When the head depressor is placed on the target, the effective planing area is increased so that the downward force due to the resistance of the water is increased. Figure 15 and Table 3 give typical data on the streaming of the target when the head depressor is used.

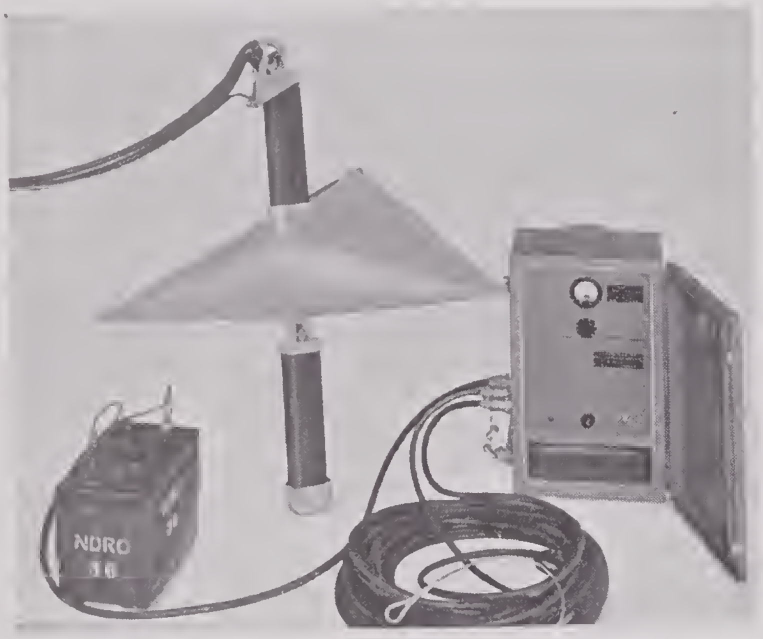


FIGURE 16. Practice target, model SR-5.

Practice Target Model SR-5

The model SR-5 practice target, developed by UCDWR, is a towed underwater echo repeater especially adapted for echo-ranging practice at slow speeds in shallow water. Its steel-plate body is a wing-like structure upon which two CJ-1 transducers are mounted. The associated amplifier (model S5-AB) and its 6-v battery power supply are located aboard the towing vessel. The target is towed by means of a 30-ft flexible steel cable attached to a tow point built into an extension of the upper transducer mounting cap. A 7½-lb lead disk, attached to the lower transducer mounting cap, provides stabilizing ballast.

Transducer and battery cables and a 30-ft flexible steel tow cable complete the equipment. A 7½-lb lead disk provides stabilizing ballast. The model SR-5 practice target is shown in Figure 16.

The target body is a wing-like structure built of 16-gauge steel plate and made watertight by welded seams. The flat surfaces of the body are internally strengthened against external pressure by five longitudinal rib members. A tube structure extends through the center line of the body from top to bottom and provides a framework for the transducer mounting caps. The stabilizing disk is attached to the lower transducer mounting cap; the tow point is built into an extension of the upper transducer mounting cap.

The cap screws used to secure the transducer mounting caps in place (see Figure 17) are drilled throughout their entire length in order to allow the tubes to flood with sea water. This

TABLE 3. Approximate operating characteristics of model SR-2 with head depressor.

Cable length (ft)	Speed (knots)	Depressor setting (angle from horizontal, degrees)	Target depth (ft)
20	4	15	10
20	5	15	10.5
20	6½	15	11
25	4	15	10
25	5	15	11.5
25	6	15	12.5
25	6½	15	13
32	4	15	12
32	5	15	13.5
32	6	15	14.5

flooding is necessary to prevent distortion of the uniformity of the transducer response pattern.

In order to avoid turbulence immediately behind the transducer, mounting structures, and the transducers themselves, a membrane-type fairing made of ⅛ in. thick neoprene is stretched over each mount and transducer (see Figure 17). Each fairing is free-flooding and does not materially affect sound transmission.

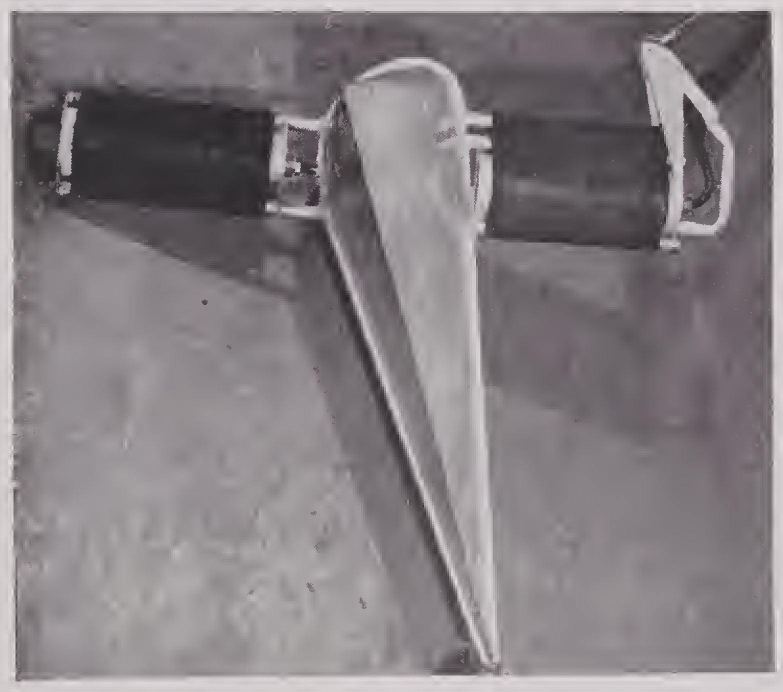


FIGURE 17. Transducer mountings in target model SR-5.

Transducers used in the SR-5 practice target are type CJ-1, discussed earlier in this chapter.

The amplifier is model S5-AB, which is almost identical with model U2-AB used in the SR-2 practice target. Values and specifications for these amplifiers are given in Table 1. Power for the amplifier is supplied by a standard 6-volt, 150-ampere-hour storage battery which, when fully charged, provides about 16 hours of satisfactory operation.

TOWING CHARACTERISTICS

The SR-5 practice target body is so designed that it will dive immediately when towed through the water at any speed from 3 to 6 knots. When the target is stabilized, the center line through the two transducers is vertical. The divided surface of the body performs the double function of providing both vertical and horizontal stabilization. The displacement of the target body in salt water, when it is supporting the three cables, provides an excess positive buoyancy of approximately 15 lb.

The final target depth is determined by the length of the tow cable. This depth, measured from the bottom of the lower transducer to the surface of the water, will have the values listed in Table 4 when the tow craft has a speed of 4 to 6 knots.

TABLE 4. Operating characteristics of model SR-5 at a speed of 4 to 6 knots.

Length of cable in water (ft)	Depth (ft)
10	9
15	12
20	17
25	22
30	27

Chapter 11

TRAINING EQUIPMENT FOR ANTISUBMARINE WARFARE SONAR MAINTENANCE PERSONNEL

The main purpose of equipment designed specifically to aid in the training of ASW sonar maintenance personnel is to demonstrate or give practice in the testing of sonar gear in order to locate troubles or insure adequate performance.

The advantages of being able to conduct such training in the laboratory or training school with simulated hydrophone signals, instead of being forced to rely on dockside or sea testing, are evident. A program to develop an artificial signal generator for bench-testing and demonstration was therefore carried on at the Harvard Underwater Sound Laboratory. Parallel developments, the sound injectors and the JP amplifier demonstrator were carried out by the New London laboratory for submarine sonar maintenance personnel.

The devices designed primarily for testing purposes are covered in Division 6, Volume 18, and it may be useful to the reader to refer to that volume. A key unit in various types of testing apparatus is the *inductive echo simulator*, or *projector simulator* [PS] coils, used with sound gear monitors to simulate the signals sent or received by an actual sonar projector. PS coils have been adapted to and incorporated in various types of training equipment, including two of the devices described in this chapter.

The first of these is the *artificial sonar projector*, designed to train ASW sonar maintenance men in testing the frequency response and directivity patterns of sound projectors.

Following discussion of the artificial sonar projector, the *bearing deviation indicator* [BDI] *dynamic demonstrator*, an enlarged working model of the BDI wiring schematic, is explained. It is used to aid maintenance personnel in mastering the circuits and learning how to take voltage measurements and make operating adjustments.

The next section of the chapter gives an account of the signal generator designated *operator training equipment*, Model 9 (OTE-9). Although any signal generator with a frequency range from 18 to 25 kc may be used to activate the BDI dynamic demonstrator, OTE-9 was designed especially for use with this unit and also with regular BDI units in the teaching of trouble-shooting. This is the second of the maintenance training devices incorporating PS coils. The final section briefly describes the equipment for submarine maintenance personnel.

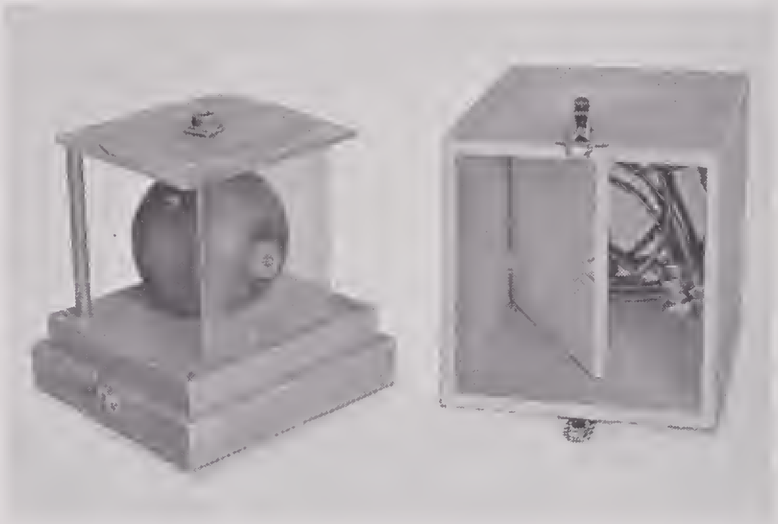


Figure 1. Artificial projector and case.

Artificial Sonar Projector

The artificial sonar projector, developed by HUSL, consists essentially of a one-third-scale mockup of a spherical sonar projector and a special coupling unit called projector simulator [PS] coils. Other components are a frame to support the "exciter" coil and the bearing scale and a carrying case. The PS coils, when used with a signal generator and an output indicator, will give measurements illustrative of the frequency response and directivity patterns of either magnetostrictive or crystal split or unsplit sonar projectors.

11.1 INTRODUCTION

Early attempts to obtain a realistic artificial signal for testing purposes led to the use of disk reproduction of actual signals received during echo-ranging operation with QC gear. Since this was not satisfactory, the development of a completely artificial signal source was undertaken. To meet the requirements imposed in making directivity tests with BDI gear, first a simple RC phase-shifting arrangement was developed to provide two echo signals, differing in phase by a known and controllable amount. This was then discarded in favor of a more satisfactory method, utilizing the characteristics of mutual induction between two flat coils, one of which slides laterally across the face of the other (PS coils).[1]

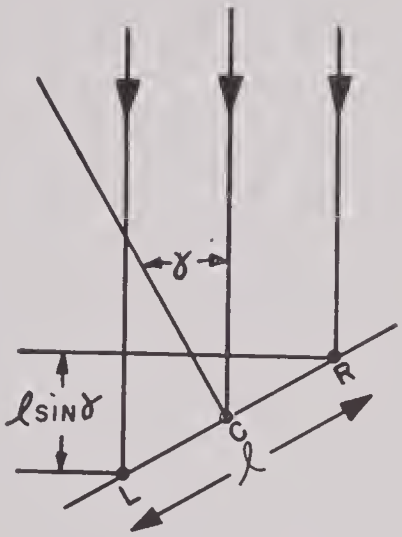


FIGURE 2. Array of point hydrophones.

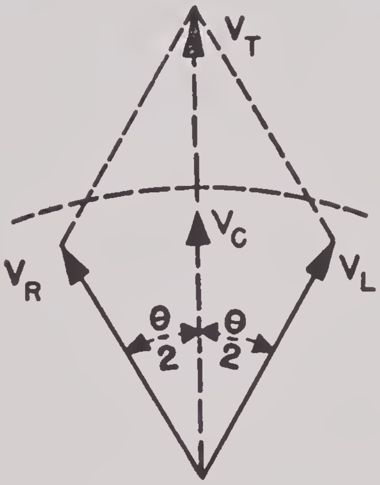


FIGURE 3. Vectors for sound arriving from the right.

As incorporated in the artificial sonar projector, a single exciter coil mounted in a fixed position alongside a hollow, rotatable, wooden sphere, receives input signals from an external generator. Within the sphere's surface, a group of pickup coils is so arranged that rotation of the sphere will result in lateral motion of the individual pickup coils across the face of the external, exciting coil. The induced voltages in a pair of quadrature pickup coils are combined, through a suitable phase-shifting arrangement, with the voltage set up in a single amplitude pickup coil to give an output simulating the response of a directional projector. The remaining coils of the group, controlled by a switch, are so mounted that the minor lobes, characteristic of a poor projector, can be secured when desired.

11.2 THEORY

In devising the PS coil arrangement, the output of an actual sonar projector was analyzed into a set of voltage vectors and the directivity effects on magnitudes and phase angles were determined. The possibility of using the variation in mutual induction between coils to obtain duplication of this output was then recognized and design details were worked out experimentally. The procedure followed is summarized below.

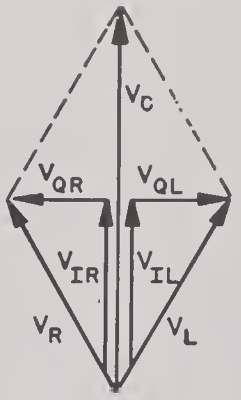


FIGURE 4. Resolution of vectors V_R and V_L.

OUTPUTS OF PROJECTOR HALVES

Point Projectors. Consider first the idealized case of two identical nondirectional point hydrophones *L* and *R* (Figure 2) separated by a distance *l* which is of the order of magnitude of one wavelength of sound. If a plane wave approaches along a direction making an angle γ with the normal to the line *LR*, the voltages generated in the two hydrophones will differ in phase by an amount θ given by the equation,

$$\theta = \left(\frac{l}{\lambda}\right) 360 \sin \gamma \text{ degrees},$$

where λ is the wavelength of sound. It is convenient to express phase with reference to that in a third point hydrophone C located at the mid-point between L and R. If γ is measured clockwise from the normal to the direction of the incident sound, in line with Navy practice, then for small positive values the phase of the voltage $\mathbf{V}_L$ generated in L lags $\mathbf{V}_C$, that in C, by $\theta/2$; similarly, $\mathbf{V}_R$ leads $\mathbf{V}_C$ by $\theta/2$. These vectors are shown in Figure 3, in which a lead is represented by an anticlockwise rotation from the reference, $\mathbf{V}_C$. Since the hydrophones are nondirectional, the magnitudes of the voltages generated are independent of γ, so that $\mathbf{V}_R = \mathbf{V}_L = \mathbf{V}_C$ in magnitude. Consequently $\mathbf{V}_T$, the vector sum of $\mathbf{V}_R$ and $\mathbf{V}_L$, is always either in phase with $\mathbf{V}_C$, or 180 degrees out of phase, regardless of the intensity of the signal or the direction of approach. For sound approaching from the left (γ negative) $\mathbf{V}_L$ leads $\mathbf{V}_C$ and $\mathbf{V}_R$ lags $\mathbf{V}_C$, but $\mathbf{V}_T$ remains in phase (+ or −) with $\mathbf{V}_C$.

OUTPUTS FROM HALVES OF UNIFORM LINE

If the nondirectional hydrophones are replaced by the halves of a uniform-line hydrophone extending from R to L (Figure 2), the phases of the outputs of the halves will be the same as those of two nondirectional hydrophones, one located midway between L and C and the other midway between R and C. This is because the line may be considered as a row of point hydrophones, each generating the same voltage, the phase of these voltages differing from that of $\mathbf{V}_C$ by amounts proportional to their distances from C.

These voltages add vectorially into $\mathbf{V}_R$ and $\mathbf{V}_L$, as in Figure 3, and $\mathbf{V}_R$ and $\mathbf{V}_L$ have the phase relationship associated with the mid-points of the halves. The magnitudes of these vectors do depend upon direction, since the line hydrophones have definite directionality.

OUTPUTS FROM HALVES OF A CIRCULAR PROJECTOR

A typical sonar projector with a circular face, electrically split for BDI operation, behaves like the split line except that the directivity pattern of a half-circle differs from that of a uniform line, and the effective distance between halves is the distance between the acoustical centers of the two halves. With these qualifications, it is possible to speak of voltages $\mathbf{V}_R$ and $\mathbf{V}_L$ with phase dependent on γ, but with amplitudes also depending on γ because of the directionality of the projector halves.

In-Phase and Quadrature Components. The electromotive forces $\mathbf{V}_R$ and $\mathbf{V}_L$ of the two halves of a circular projector excited by a plane wave of sound may be resolved into components in phase with and at right angles to $\mathbf{V}_C$, the hypothetical electromotive force at the mid-point, as shown in Figure 4. In this figure the in-phase components have subscripts I and the ones normal to them, 90 or 270 degrees out of phase with $\mathbf{V}_C$, have subscripts Q.

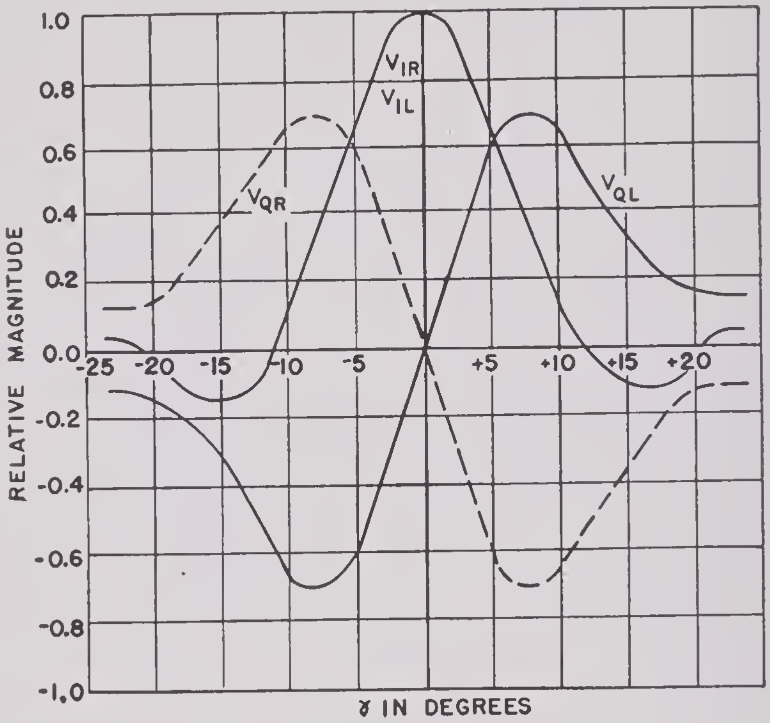


FIGURE 5. Variations of $\mathbf{V}_{IR}$, $\mathbf{V}_{IL}$, $\mathbf{V}_{QR}$, and $\mathbf{V}_{QL}$ with γ.

The dependence of the amplitudes on the angle γ depends, as stated before, on the directivity patterns of the halves. On the basis of typical projector patterns (16 degrees wide, 10 db down for the unsplit projector) the variation with γ of the magnitudes $\mathbf{V}_{IR}$, $\mathbf{V}_{IL}$, $\mathbf{V}_{QR}$ and $\mathbf{V}_{QL}$ is shown by Figure 5. These data were computed for a split circular projector of diameter 4λ, which is approximately equivalent to a nonshaded QC projector at 24 kc. Shading, as well as a change in frequency, will produce only minor changes in the form of the curves, although the scale of γ must be somewhat contracted to represent a wider major lobe.

11.3 SIMULATION OF OUTPUTS OF PROJECTOR IN RECEPTION

Production of In-Phase and Quadrature Voltages

While various means may be used to control voltages in any desired way as a function of mechanical displacement, a suitable method is through variation of mutual inductance. If one coil of a pair carries alternating current, the voltage induced in a second coil will be proportional to the mutual inductance between them. The problem thus becomes essentially one of finding the constructional requirements of coil arrangements that will give the desired variation of mutual inductance with displacement.

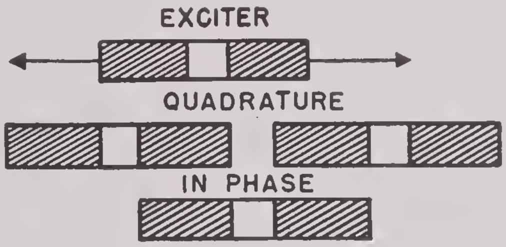


Figure 6. Exciter coil, quadrature coils, and in-phase coil.

It was found that an exciter coil with a radially distributed winding, moved laterally with respect to a similar pickup coil, gives a voltage curve almost exactly duplicating the $\mathbf{V}_{IR}$ and $\mathbf{V}_{IL}$ curve of Figure 5 when plotted against displacement X. This displacement may be used to represent changes in γ. Likewise the same exciter coil in conjunction with a pair of similar pickup coils connected in phase opposition gives voltage curves duplicating either the $\mathbf{V}_{QR}$ or $\mathbf{V}_{QL}$ curves of Figure 5, depending upon polarity. By adjusting the sizes and numbers of turns in a combination of in-phase and quadrature pickup coils, as shown in Figure 6, the required relationships between their respective outputs are achieved.

Phase-Shifting Means

The voltages induced in the in-phase (or amplitude) and quadrature coils are in phase agreement, but theory requires that they be combined in phase quadrature to give the desired results. A phase difference of 90 degrees must therefore be introduced. If operation is to be over only a very narrow frequency range, the 90-degree phase shift can conveniently be obtained with a single lag-line type of phase shifter. If operation over a broader frequency range is required, it has been found desirable to use a lead-lag combination. A 45-degree lead line is inserted in the output line from the amplitude coil and a 45-degree lag line in the output from the quadrature coil. As the frequency changes, the changes in the phase shifts of these lines are approximately complementary, so that a difference of close to 90 degrees is maintained over more than an octave.

Combining Circuit

The simplest method of combination is through series connection. When the projector to be simulated uses the parallel split connection of two halves (i.e., voltages in phase with respect to the common return for sound arriving on the axis), it is convenient to adjust the output of the quadrature coils to double the required value and to use a center-tapped resistor as the terminating impedance for the phase shifter. The center tap is connected through the amplitude coil circuit to the output common terminal and the ends are connected through isolating resistors to the output R and L terminals. When a series split projector is to be simulated, the output of the amplitude coil is made double and is center-tapped.

Method of Obtaining Required Frequency Response

The required frequency response is obtained by tuning the exciter coil circuit so that the current through it varies properly with frequency. Since the voltages induced in the pickup coils vary directly with the current through the exciter coil, the required variation of projector output voltage with frequency is obtained. To simulate the frequency response of a magnetostriction projector, the exciter coil may be series-tuned with a suitable capacitor. Sharper resonance may be achieved with an additional high-Q coil in the series circuit. Leaving the exciter coil untuned results in the flat response characteristic of most types of crystal projectors.

11.4 SIMULATION OF PROJECTOR IN TRANSMISSION

In making measurements on the transmitting properties of an actual transducer, power is fed to the projector, and the voltage output of a hydrophone at a distant point in the water (preferably not less than four projector diameters distant) is observed. Combination of the sound pressures produced at the hydrophone by the different elements of the projector gives a resultant pressure which depends upon the orientation of the projector. The output voltage of the hydrophone accordingly varies with projector rotation, and its measurement yields the transmitting directivity pattern.

In order to simulate the foregoing process with the artificial projector, the operating functions of exciter and pickup coils may be interchanged. The output terminals of the PS coil arrangement may be connected to a signal source, and voltages will be induced in the exciter coil. In this case, since the unsplit connection is used, the two high sides of the PS coil arrangement are connected together and since equal currents then flow through the quadrature coils, their effect vanishes. The directivity pattern, as in the case of the unsplit receiving connection, is therefore determined entirely by the geometry of the amplitude coil and the exciter coil.

11.5 CONSTRUCTION OF ARTIFICIAL PROJECTOR

The artificial projector pictured in Figure 1 consists of the following.

1. A model spherical projector unit which contains the projector simulator coil assembly and associated circuits.
2. A frame which supports the exciter coil and bearing scale and on which the model projector unit is mounted.
3. A carrying case.
4. Cables for connecting the projector with the associated equipment.

The projector unit is a hollow wooden sphere (see Figure 1) designed to be a one-third scale model of a standard spherical sonar projector of the QC type. It can be rotated about a vertical axis and a bearing scale indicates the degree of rotation.

Located inside the sphere is the PS coil assembly which comprises amplitude and quadrature pickup coils, phase-shifting means, and a combining circuit. As the artificial projector is rotated, the amplitude and quadrature pickup coils approach and pass an energized exciter coil (see Figure 1) mounted just outside the wooden sphere. As this occurs, varying voltages are induced in the pickup coils and are then fed into the phase-shifting and combining circuits, producing the main and minor lobes of the directivity pattern. The pickup coils are designed to give the same major beamwidth as that found in the directivity pattern of a QC projector that resonates to a similar frequency. The construction of these coils and their rela-

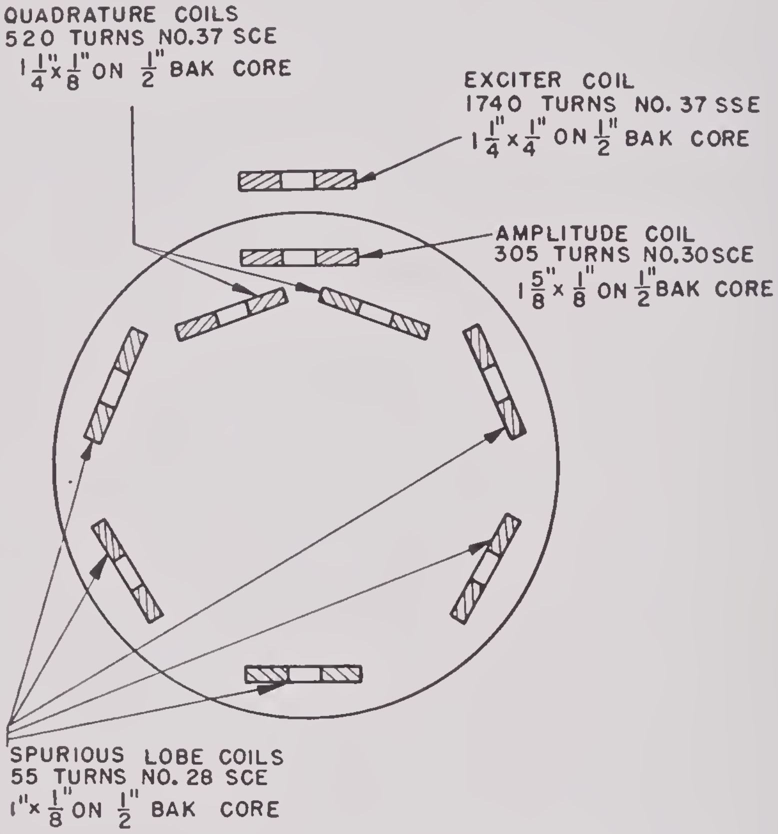


FIGURE 7. Top cross-sectional view of artificial projector.

tive locations are shown in Figure 7. A switch is provided for cutting in additional amplitude coils to produce spurious side and back lobes.

The exciter coil is mounted on a Lucite plate which is an integral part of the frame. The magnetic field of this coil induces voltages in the pickup coils within the sphere as described above. The impedance of the exciter coil is approximately 100 ohms and a type OAX *sound gear monitor*[2] can therefore be readily used as the signal source. The input connection to the exciter coil is made to an AN connector mounted on the base of the frame.

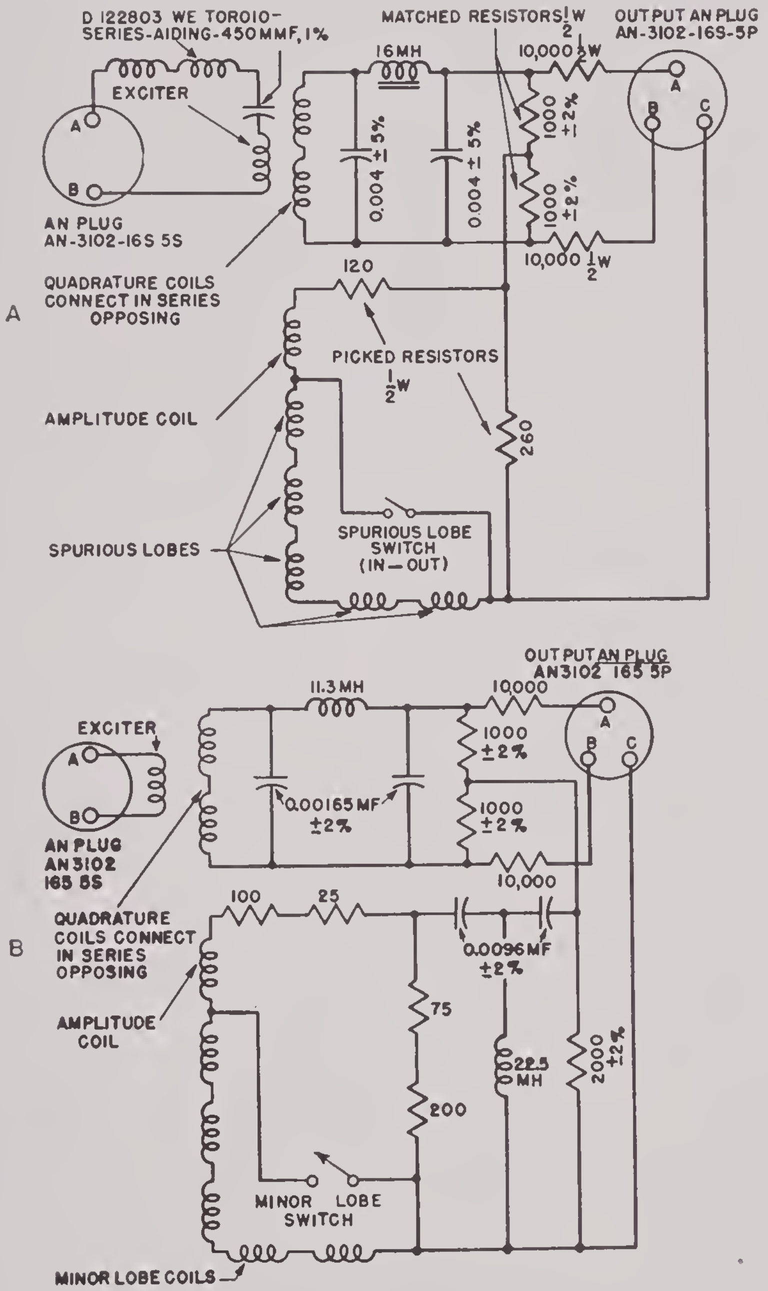

D 122803 WE TOROIO-
SERIES-AIDING-450 MMF, 1%
MATCHED RESISTORS 1/2 W
OUTPUT AN PLUG
AN-3102-16S-5P
16 MH
10,000 1/2 W
EXCITER
A
B
C
1000 ±2%
0.004 ± 5%
0.004 ± 5%
1000 ±2%
AN PLUG
AN-3102-16S 5S
10,000 1/2 W
120
QUADRATURE COILS
CONNECT IN SERIES
OPPOSING
A
PICKED RESISTORS
1/2 W
AMPLITUDE COIL
260
SPURIOUS LOBE
SWITCH
(IN — OUT)
SPURIOUS LOBES
OUTPUT AN PLUG
AN3102 165 5P
11.3 MH
10,000
EXCITER
1000 ±2%
0.00165 MF ±2%
1000 ±2%
AN PLUG
AN 3102
165 5S
10,000
100
25
QUADRATURE
COILS CONNECT
IN SERIES
OPPOSING
B
0.0096 MF ±2%
AMPLITUDE
COIL
75
22.5 MH
2000 ±2%
200
MINOR LOBE
SWITCH
MINOR LOBE COILS

FIGURE 8. Circuit diagrams for (A) the artificial QC projector and (B) the artificial QJ split projector.

For an artificial QC magnetostriction projector, a single 90-degree lag line is used as the phase-shifting component to produce the required quadrature phase relationship between the voltages of the amplitude and the quadrature coils. It is housed within the model projector with the combining circuit, which is simply a center-tapped resistor and two isolating resistors. The output connection is an AN connector mounted on the vertical axis of rotation of the projector (see Figure 1). A schematic wiring diagram for the artificial QC projector is shown in Figure 8A. By tuning the exciter coil, the projector is made to give a frequency response similar to that of an actual QC projector. The center frequency of the projectors built at HUSL is approximately 21 kc.

To simulate the frequency response of a QJ (split crystal) projector, the exciter coil is left untuned and the phase-shifting means consist of a 45-degree lead line and a 45-degree lag line. This arrangement yields a phase difference which is essentially 90 degrees over a wide frequency range. Figure 8B is a schematic wiring diagram for this artificial unit.

When the artificial projector is connected to simulate the transmission function, signals are applied to the pickup coils in the sphere, and an output voltage is obtained from the exciter coil. Since only passive components are used, this voltage will vary with rotation of the projector in accordance with the same directivity pattern as that obtained in the receiving function. The frequency response will likewise be similar to that which obtains in reception.

The artificial projector equipment weighs 15 lb and measures 10x15 in. when enclosed in its carrying case. The top of this case also houses the necessary connecting cables (see Figure 1).

11.6 TYPICAL OPERATION

Unsplit Projector Patterns

Frequency Response Curves. The artificial projector has one resonant frequency at which its power transmission is a maximum. This frequency, together with the Q of the device, can be determined from a *transmission* frequency-response curve.

To obtain such a curve, a calibrated signal generator may be connected to the rotatable pickup coils while an output indicator is driven from the fixed exciter coil. (It is worth noting here that the present form of the device cannot safely handle the output of a high-power signal source.) The Q can be found from the response curve obtained by using the formula

$$Q = \frac{\text{Resonant frequency (kc)}}{\text{Width of curve (kc) 3 db below peak}}.$$

If the signal generator is changed to the exciter coil and output indications are taken from the pickup coils, the resonant frequency and Q for the *reception* function can be determined in similar fashion. Figure 9 shows typical curves for both transmission and reception.

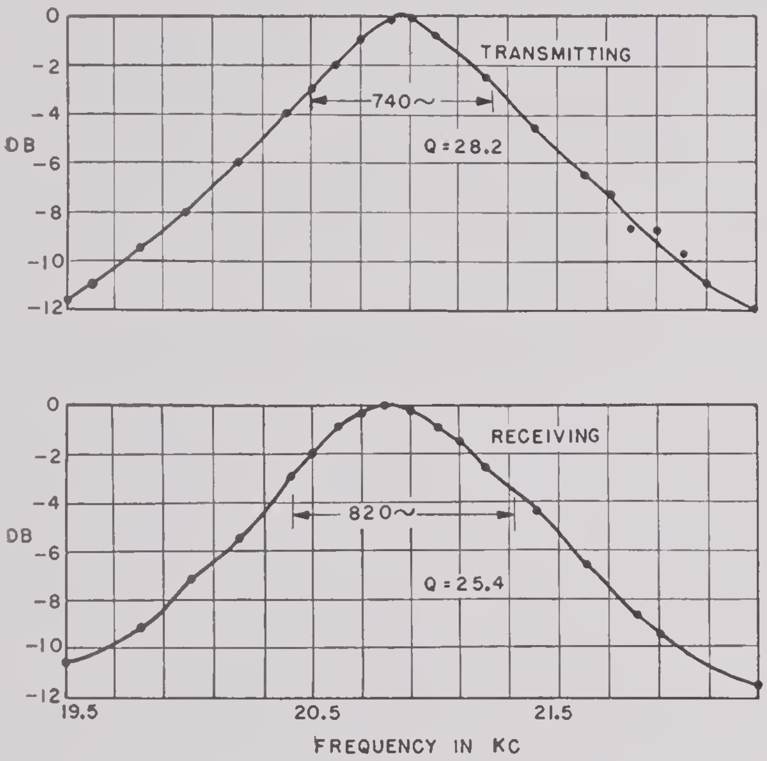


FIGURE 9. Frequency response curves at bearing 000°.

Directivity Patterns. To obtain transmitting directivity patterns, a signal may be applied to the internal pickup coils, and the output readings then obtainable from the fixed exciter coil as the projector sphere is rotated will give the information required. As before, the corresponding reception readings can be secured by interchange of the signal generator and output indicator locations. Figure 10 shows a poor pattern resulting from the use of the spurious lobe coils, whereas Figure 11 portrays the ideal pattern which may be secured when these

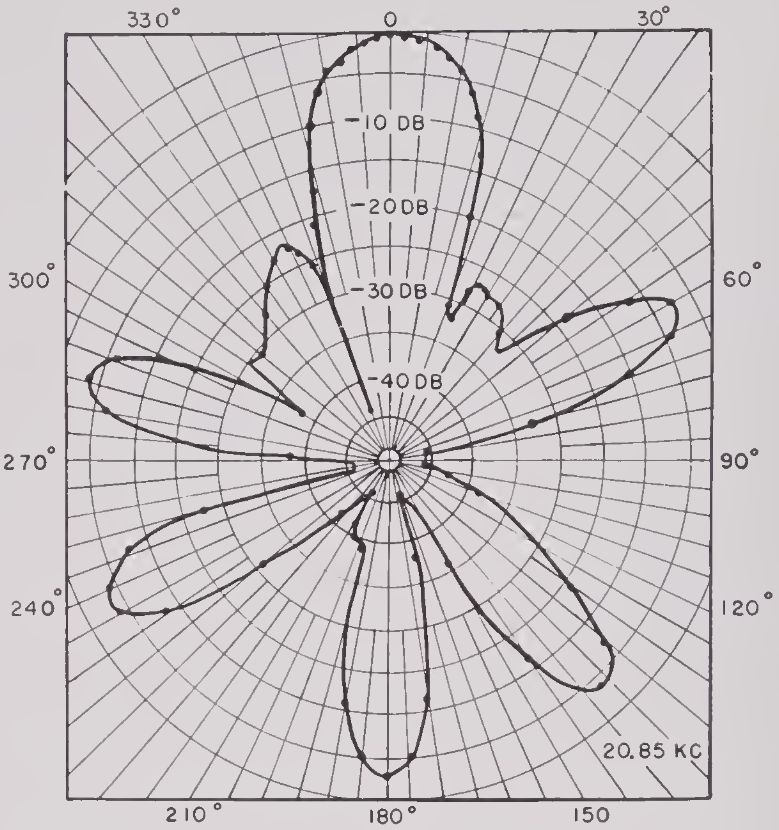


FIGURE 10. Transmitting pattern with spurious lobes in.

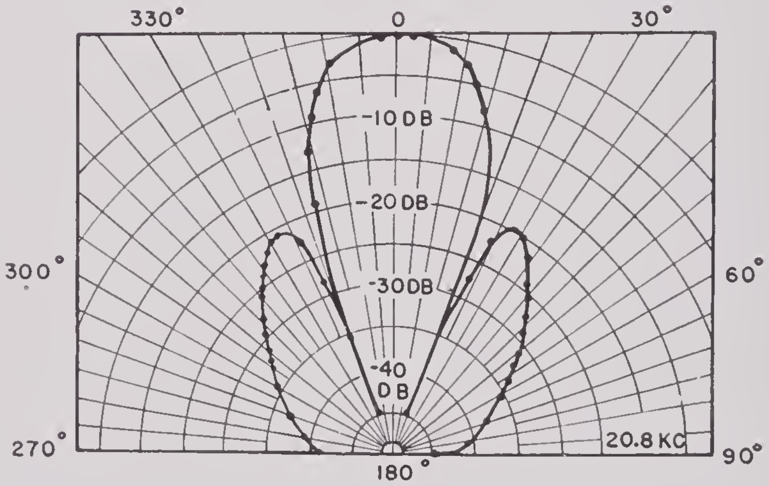


FIGURE 11. Receiving pattern with spurious lobes shorted out.

spurious lobe coils are shorted out of the circuit.

Split Projector Patterns

The displaced directional patterns typical of split projector operation can be simulated with the artificial projector when it is used with a suitable lag line. Figure 12 shows the manner in which the input circuit of a standard BDI may be utilized for this function. The individual lobe patterns are obtainable by taking outputs from the opposite ends of the line (points *A* and *C*), while an undisplaced pattern will follow if the output is drawn from the center tap (point *B*). Figures 13 and 14 show results secured with a standard BDI lag line and with a *split projector test unit* [SPTU] lag line, respectively.

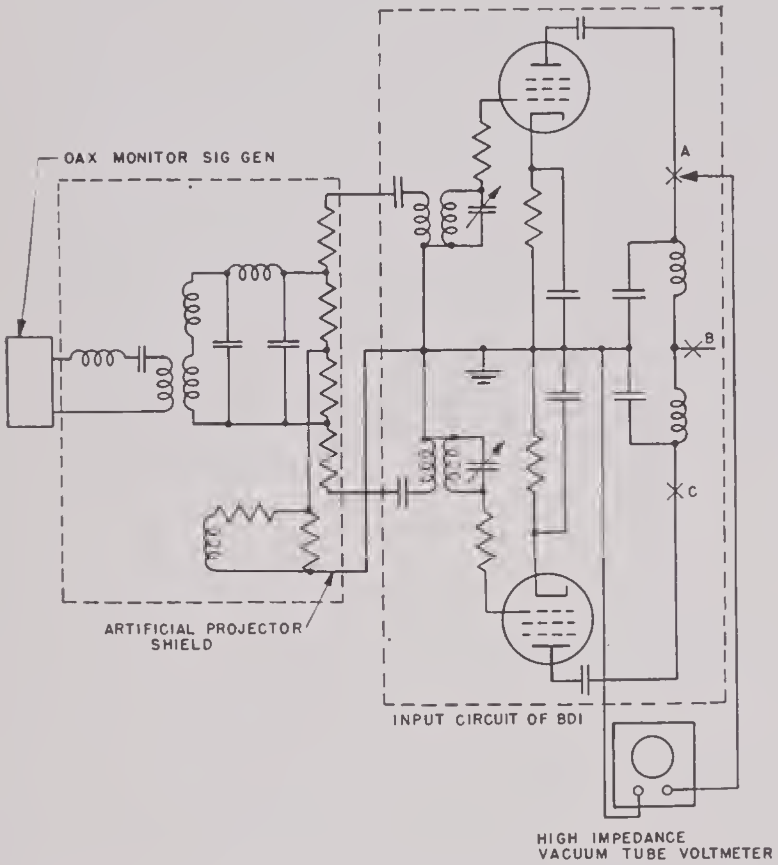

OAX MONITOR SIG GEN
A
B
C
ARTIFICIAL PROJECTOR SHIELD
INPUT CIRCUIT OF BDI
HIGH IMPEDANCE VACUUM TUBE VOLTMETER

FIGURE 12. Circuits of artificial projector and BDI input.

11.7 CONCLUSION

The artificial projector in its present form is adequate for simulating the performance of existing sound projectors. It is relatively simple to build a satisfactory model with electrical characteristics resembling almost any type of split or unsplit sonar projector. Future, more complicated, projectors may require modification or additional development of the device. In view of the continuing need for adequate personnel training equipment, such development is recommended.

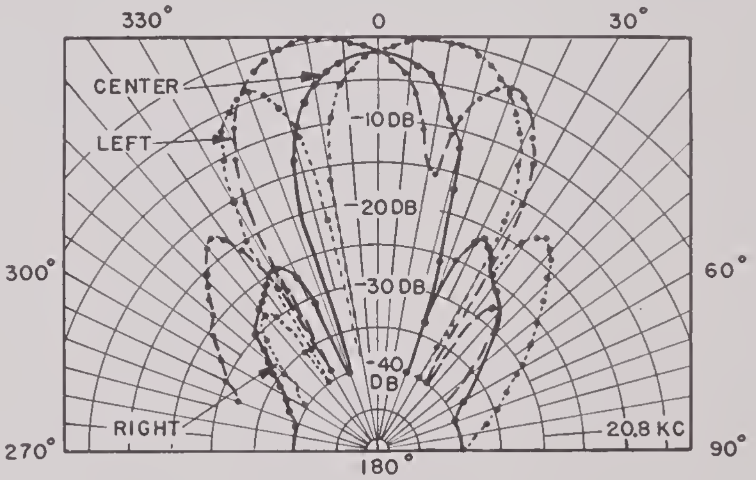


FIGURE 13. Receiving pattern as split projector with BDI lag line.

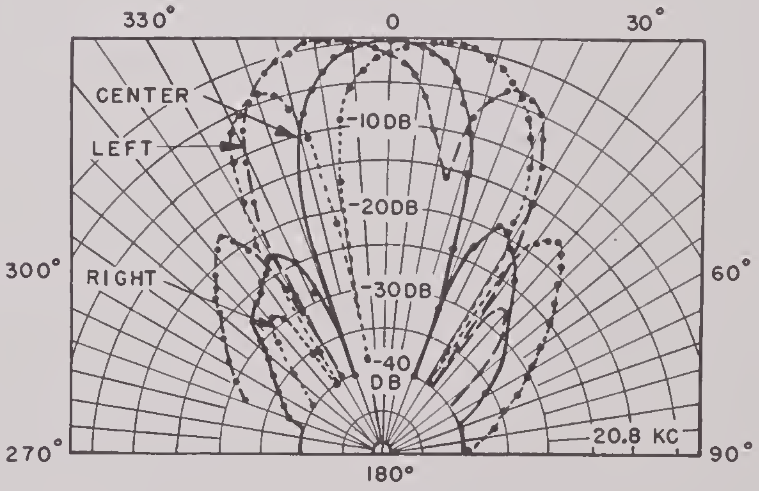


FIGURE 14. Receiving pattern as split projector with SPTU.

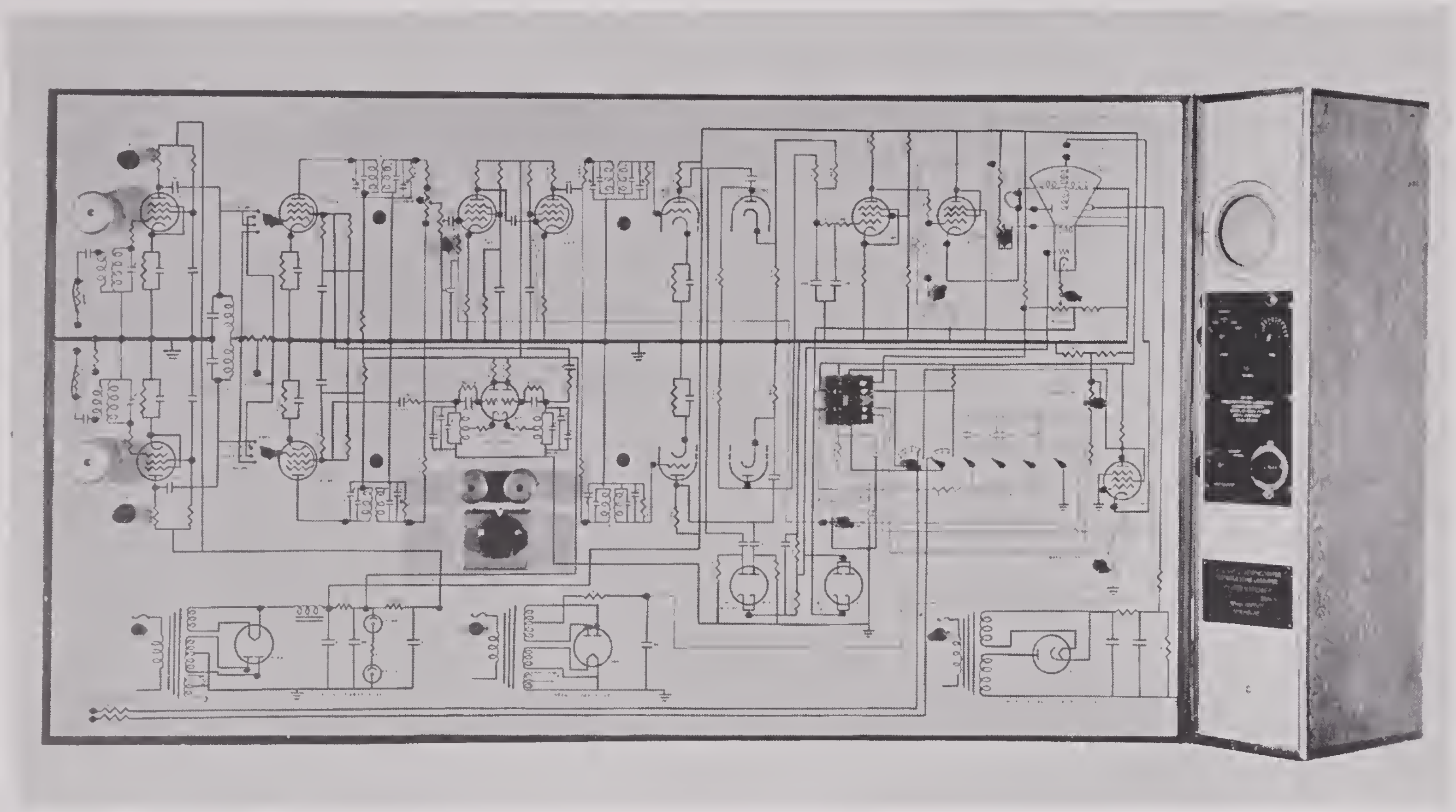


FIGURE 15. BDI dynamic demonstrator—front view.

BDI Dynamic Demonstrator

The BDI dynamic demonstrator, developed by HUSL, is an enlarged working model of the BDI circuit diagram, with actual controls incorporated in it. A signal may be injected to demonstrate the operation of the circuit and the method of making adjustments. This display unit has been useful primarily in teaching sound maintenance men the X-3 BDI circuit and how to keep it in adjustment.

11.8 INTRODUCTION

The BDI dynamic demonstrator was developed to meet the need for a large classroom display schematic of the BDI which would show the circuit not only in a static but also in a dynamic condition. This involved enlarging and rearranging the regular book schematic to permit mounting it on a board and incorporating in it the various controls necessary to make it serve as a working model (see Figure 15).

The demonstrator can be used for instruction in step-by-step signal tracing and voltage and resistance measurements. It is also suited for laboratory experiments dealing with voltage measurements, signal tracing, and operating adjustments (including tuning and phasing input transformers, balancing, oscillator adjustments, horizontal centering, focusing, adjustment of range-start control, adjustment of range-limit control, intensity adjustments, range switch adjustments, and gain adjustments).

The BDI dynamic demonstrator was not designed for teaching trouble shooting, for which purpose an actual BDI unit is more suitable. Although the 7- and 10-kc filters can be aligned from the front panel, this should be done for maintenance of the demonstrator only, and not as a regular laboratory experiment.

11.9 GENERAL DESCRIPTION

The BDI dynamic demonstrator is a large X-3 schematic diagram drawn in colors on a 6x3 ft panel on which are mounted and connected the various resistors, condensers, tubes, coils, and other components which go to make up a standard X-3 BDI unit. Thus it constitutes a working model of the BDI unit in which the parts are arranged to conform to the schematic diagram rather than for ease of wiring, as is done in the actual BDI unit. For convenience in handling, the panel is mounted in a box 13 in. deep, which may be set on a table in front of the class (see Figure 15).

The cathode-ray tube and a dummy BDI[a] panel are mounted in a separate box at the end of the larger one, which is hinged so that the face of the tube may be turned toward the instructor while he is making adjustments and may then be swung back into a plane parallel with the rest of the panel for demonstration purposes.

The only facilities required for the use of the BDI dynamic demonstrator are a 110-volt, 60-c source of alternating current and any signal generator having a frequency range from 18 to 25 kc. It is recommended, however, that the special BDI signal generator (OTE-9), designed for use with the unit and described in the next section, be employed.

11.10 CONCLUSION

Eight units of the BDI dynamic demonstrator were constructed at HUSL. The first of these was of slightly different construction from the rest in that the cathode-ray tube and dummy BDI panel were mounted on the main panel. This Model 1 was tried out successfully by the West Coast Sound School and from the suggestions made there Model 2, described above, was developed. Model 2 then served as prototype for the remaining six.

This development has shown conclusively that large-scale working models of schematic wiring diagrams can be used effectively in connection with quite complicated electronic equipment. Their value as teaching aids has been amply proved through the use of the BDI dynamic demonstrator in Navy sound schools and matériel schools.

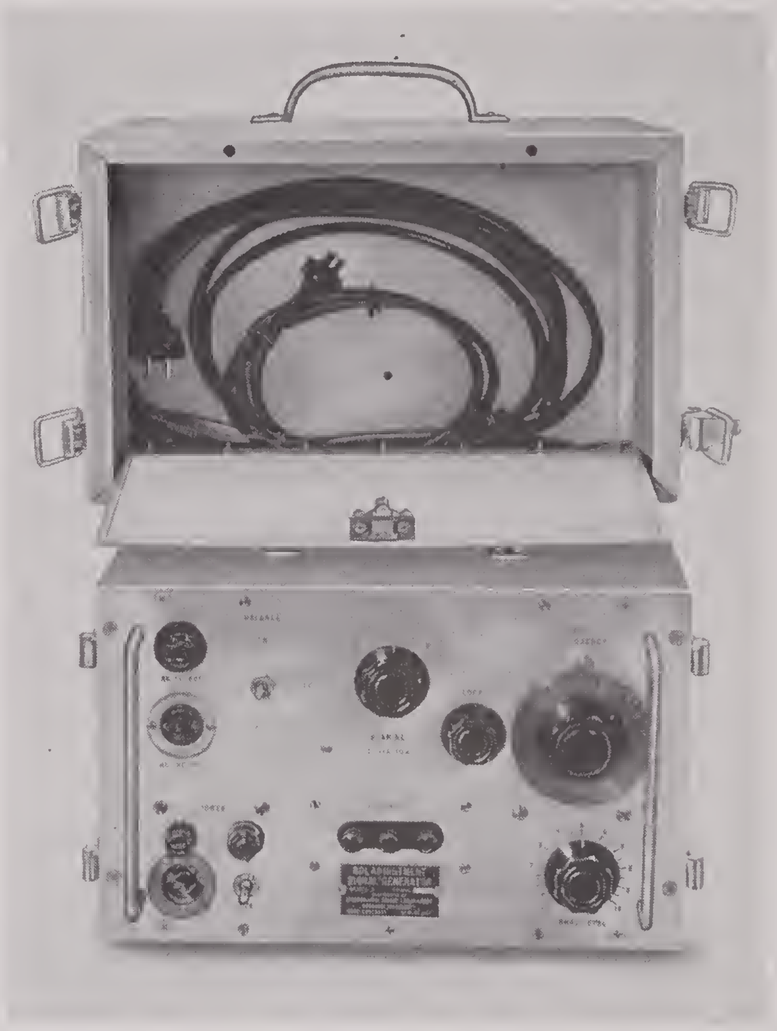


FIGURE 16. OTE-9 (BDI signal generator).

Bearing Adjustment Signal Generator [OTE-9]

The BDI adjustment signal generator, alternatively called operator training equipment model 9 [OTE-9], was designed by HUSL to serve as a signal source for demonstrating BDI action with either a BDI dynamic demonstrator board or a standard BDI unit. The complete OTE-9 equipment is contained in a two-unit metal case; one part of the case houses the OTE-9 electronic unit, and the other provides space for carrying cables and other accessories. The electronic unit furnishes either continuous or echo-like signals, and sweep relay keying pulses for the associated BDI equipment. The signal frequency is variable from 17 to 26 kc; the output level may be adjusted from 0 to 30 mv. A set of projector simulator [PS] coils is used to produce a varying phase difference between the two halves of the signal to simulate bearing deviation. No provision is made for simulating reverberation deflections on the BDI

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[a] For a complete discussion of the theory and operation of BDI circuit, see Division 6, Volume 15, Chapter 5.

screen, since they are not considered absolutely necessary for the purpose in view and their omission permits considerable simplification of the design.

11.11 INTRODUCTION

During the program of development of bearing deviation equipment at HUSL, various generators were constructed to provide signals for purposes of demonstration, training, test, and alignment. Some of these were designed to offer realistic simulation of reverberation, noise, and echo effects. For the purpose of alignment and adjustment alone, however, these requirements could be simplified.

The device here described, OTE-9, is a simplified signal generator intended to provide either continuous or echo-like signals suitable for obtaining right or left deflections on the BDI. It was designed in this simplified fashion primarily to serve as a signal source for the BDI dynamic demonstrator, although it may also be used to generate test signals for any routine adjustments of BDI equipment.

The specific requirements set up for OTE-9 were as follows. The signal furnished should have a frequency adjustable over the range of 17 to 26 kc, an amplitude adjustable from 0 to 3 mv for a bearing deviation of 0 degree, an echo with a duration of 65 yd at 1,000-yd range, and the possibility of manual control of the signal by using a test key. The unit's projector-simulator directivity should be graduated in terms of a standard QC projector and limits for deviation test points should be provided. The output impedance of the signal source was to be 200 ohms resistive per projector half. Finally, the generator was to provide a d-c pulse to operate the BDI sweep relay at a 2,000-yd range scale rate.

11.12 GENERAL DESCRIPTION

A two-unit metal case, as shown in Figure 16, houses all OTE-9 equipment. All controls and cables are mounted on the front panel of the electronic unit. The oscillator can be tuned by means of a calibrated dial over the frequency range from 17 to 26 kc, and the output level can be varied from 0 to 30 mv. Switches are provided for a-c power, for selection of a continuous output signal or a delayed-echo pulse simulating 1,000-yd range, and for BDI setting (left, center, or right). In addition, a push-button instantaneous contact switch is included for use as a test key to produce abrupt variations in signal level for adjustment of the BDI balance control.

Also on the front panel are receptacles for a-c power input, for supplying a-c power to the BDI, and terminals for supplying the signal input to the BDI and the keying pulse to the BDI sweep relay.

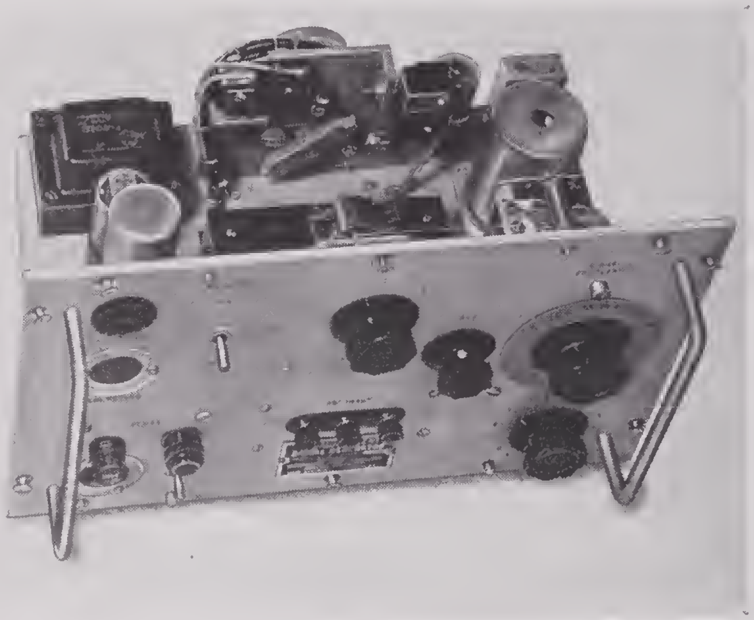


FIGURE 17. OTE-9, electronic unit removed from housing.

Figure 17 is an interior view of the electronic unit. The PS coil assembly is in the center immediately behind the bearing deviation control knob, which is used to turn the exciter coil left or right.

11.13 DESCRIPTION OF CIRCUIT

The circuit diagram for OTE-9 is shown in Figure 18. The oscillator, V-101A, is a conventional cathode-stabilized type that uses one half of a 6SN7 tube. The other half of the 6SN7 (V-101B) is used as a cathode follower to isolate the oscillator and to provide a low-

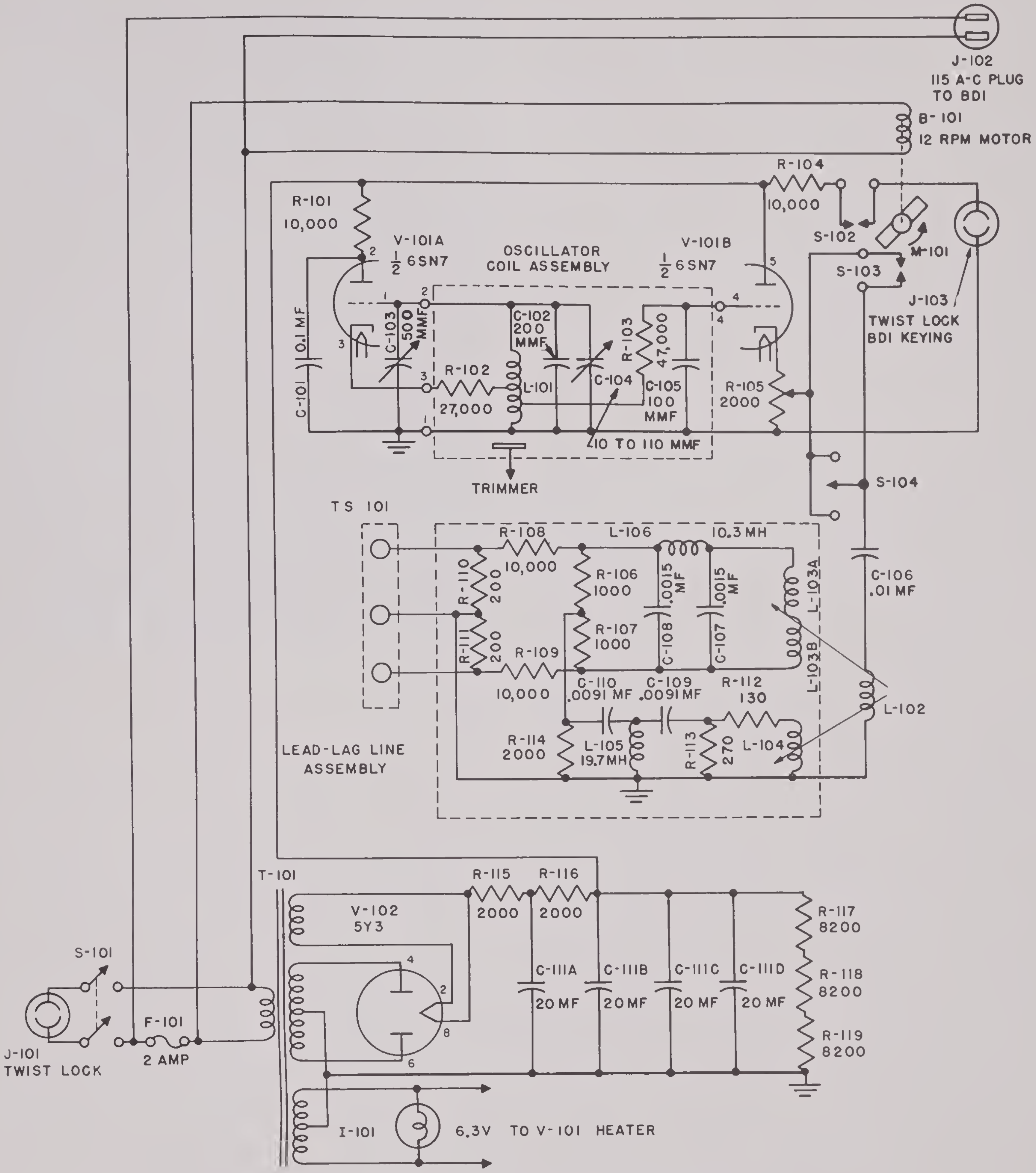

J-102
115 A-C PLUG
TO BDI
B-101
12 RPM MOTOR
R-104
10,000
S-102
M-101
S-103
J-103
TWIST LOCK
BDI KEYING
R-101
10,000
V-101A
½ 6SN7
OSCILLATOR
COIL ASSEMBLY
V-101B
½ 6SN7
C-101 0.1 MF
C-103 500 MMF
C-102
200
MMF
R-102
27,000
L-101
R-103 47,000
C-104
C-105
100
MMF
R-105
2000
10 TO 110 MMF
TRIMMER
S-104
TS 101
R-108
10,000
L-106
10.3 MH
R-110 200
R-111 200
R-106
1000
R-107
1000
C-108 .0015 MF
C-107 .0015 MF
L-103A
L-103B
C-106
.01 MF
R-109
10,000
C-110
.0091 MF
C-109
.0091 MF
R-112
130
L-102
R-114
2000
L-105
19.7 MH
R-113 270
L-104
LEAD-LAG LINE
ASSEMBLY
T-101
R-115
2000
R-116
2000
V-102
5Y3
R-117
8200
R-118
8200
R-119
8200
C-111A
20 MF
C-111B
20 MF
C-111C
20 MF
C-111D
20 MF
S-101
F-101
2 AMP
J-101
TWIST LOCK
I-101
6.3V TO V-101 HEATER

FIGURE 18. Schematic diagram for OTE-9.

impedance match for the projector simulator coils, discussed in Section 11.2. The coupling resistance is a 2,000-ohm potentiometer that is used to control signal level.

The output of the cathode follower goes to two sets of switch contacts, connected in parallel, that allow control of the signal reaching the projector simulator (PS) coils. The first switch, S-104, on the panel, is an instantaneous type used as a test key to give signal pulses for adjustment of BDI balancing. The second set of contacts, S-103, is operated by the motor-driven cam M-101. This cam, shown in Figure 17, first activates the BDI sweep relay to start the sweep through contact S-102, then sends a short delayed 65-yd echo pulse into the projector simulator coils, L-102, L-103A, L-103B, and L-104, at approximately 1,000-yd range.

In the OTE-9, the PS coils are mounted so that the exciter coil can be moved for bearing deviation by a knob on the front panel (see Figure 16). Detents are provided for centering the coils and for positioning them for standardized right and left deflections on the BDI. The detents can be removed to allow the coils to be swept freely from right to left deflection. The coils themselves are mounted on the chassis directly behind the panel.

The lead-lag line assembly (shown schematically in the center of Figure 18) acts as a phase-shifting circuit for maintaining the phase shift more nearly constant over the 17- to 26-kc frequency range than would be true if a single-section lead or lag line were used. Each of the two sections is designed to give a 45-degree shift at the center frequency of the band to be used. The lead line is connected to the amplitude coils of the projector simulator coil assembly, while the lag line is connected to the quadrature coils; thus at center frequency the voltage from the amplitude coils is made to lead the induced voltage by 45 degrees, while that of the quadrature coils lags the induced voltage by 45 degrees, and the required 90-degree phase shift is obtained. Since the phase shift due to the lag line becomes larger with increasing frequency and that due to the lead line becomes smaller by about the same amount, the sum of the two remains approximately constant at 90 degrees (actually within 4 degrees over one octave). Resistors R-112 and R-113 provide the necessary amount of voltage for the amplitude coils and give the loading on the coil necessary to correct the phase of the output. This correction is necessary, since the lag line with 2,000 ohms impedance, acting as a load on the quadrature coils which have a high internal impedance themselves, causes the terminal voltage to differ in phase from the induced voltage.

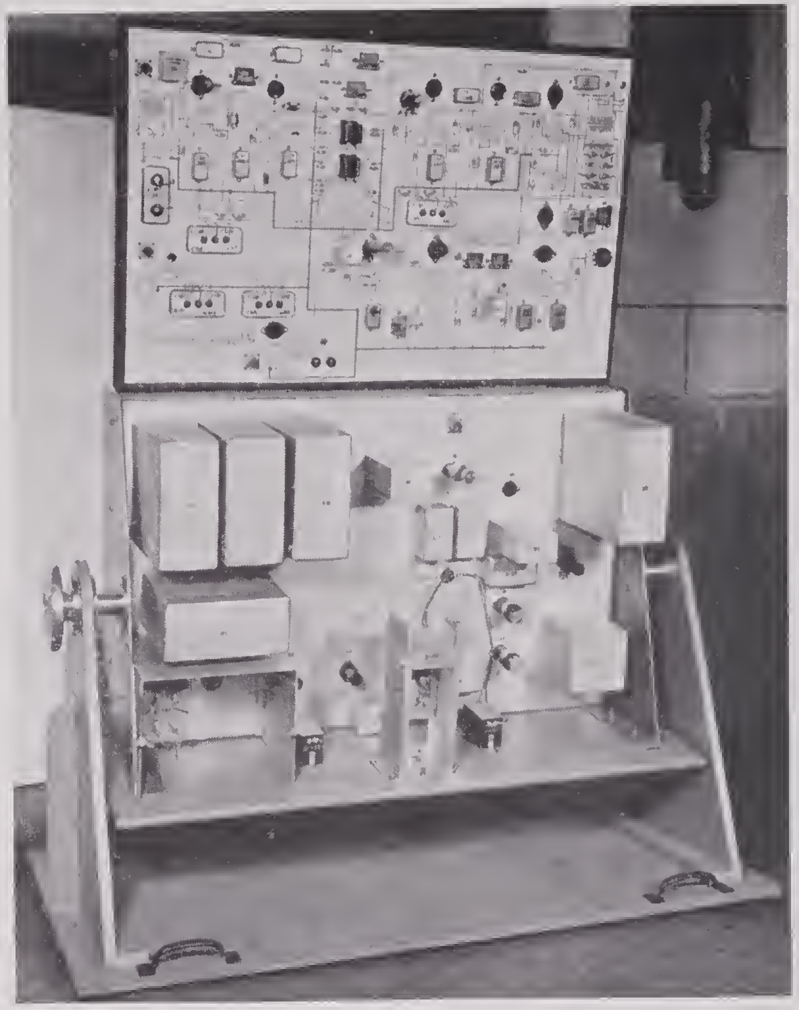


FIGURE 19. JP amplifier demonstrator.

JP Amplifier Demonstrator

The JP amplifier demonstrator, developed by CUDWR-NLL, is a large wooden model (2¼ times actual size) of a JP-1 amplifier, mounted on a pair of trunnions so that it can be rotated about its long axis. On one side wooden replicas of the amplifier parts are mounted. On the reverse side, actual parts are incorporated in a circuit diagram, with interwiring to permit tests and voltage and resistance measurements. This reverse side can either be rotated to take the place of the chassis mockup or swung into position above it, as shown in the figure. A third side, representing the amplifier front-panel controls, is at the bottom in the figure. This panel can be swung into position to demonstrate correct operating procedures. This device is the main component of the JP training kits.

11.14 CONCLUSION

The BDI signal generator OTE-9 fulfilled a definite instructional need by furnishing a single instrument to which a BDI could be connected for demonstration, thus eliminating the need for a separate signal generator and keyer. One OTE-9 was constructed to accompany each BDI dynamic demonstrator board, but World War II ended before any decision was made to procure OTE-9 units in quantity to meet signal generator needs at locations where maintenance and repair work is carried on for BDI equipment.

11.15 TRAINERS FOR SUBMARINE MAINTENANCE MEN

Special training for maintenance men who were to be responsible for submarine sonar gear paralleled the ASW sonar maintenance courses. Devices covered in this chapter, which were designed to facilitate submarine sonar maintenance instruction, are the trouble injectors and the JP amplifier demonstrator.

Trouble Injectors

Trouble injectors, designed and built by UCDWR-NLL are used with JP listening gear to set up a series of trouble-shooting problems for submarine sonar maintenance trainees. They also served with JP installations on the New London radar-sonar barge to simulate troubles commonly encountered in JP operation, in order to test the operator's alertness in noticing and reporting irregularities. A series of switches in a panel are so wired to the sonar gear that, when thrown, they have the following effects: thermal noise too high or too low; no thermal noise, but magic eye lighted; no thermal noise, magic eye not lighted; failure of magic eye to wink when magnetizing; failure of magic eye to close; failure of detector switch.

Chapter 12

TRAINERS FOR AIRCRAFT PERSONNEL USING SONAR EQUIPMENT

PROFITING BY THE experience gained when the *expendable radio sono buoy* [ERSB] was put into operation, CUDWR engineers at the New London laboratory paralleled the later stages of the development of the *directional radio sono buoy* [DRSB] with the evolution of a well-rounded training program, including the preparation of instruction manuals, course materials of all kinds, phonograph recordings, and a training device intended to portray the normal operational use of the directional buoy. The DRSB trainer is described in detail in this chapter.

For the training of Navy aircraft personnel in the recognition of signals from the ERSB, the New London laboratory likewise constructed an ERSB trainer. Pictures of this device and references to related material are included here.

Directional Radio Sono Buoy Trainer

The directional radio sono buoy [DRSB] trainer, developed by CUDWR-NLL, is a device for supplying simulated submarine propeller and water noises, with appropriate range and bearing information, to a group of student operators in a manner closely approximating reception of such information from a directional radio sono buoy. The trainer consists of a plotting board upon which a "submarine" moves over any desired course, an electronic sound generator supplying target signals, a mechanism for reproducing recorded background noises, and two FM transmitters, each representing a DRSB. The signal and noise outputs are mixed as desired and then broadcast by the FM transmitters to a number of student stations equipped with standard DRSB receivers. The student determines target bearing and propeller beat count. An instructor's repeater enables the instructor to follow the course of a given problem and, through earphones, to monitor the output of either buoy or of any of the student receivers.

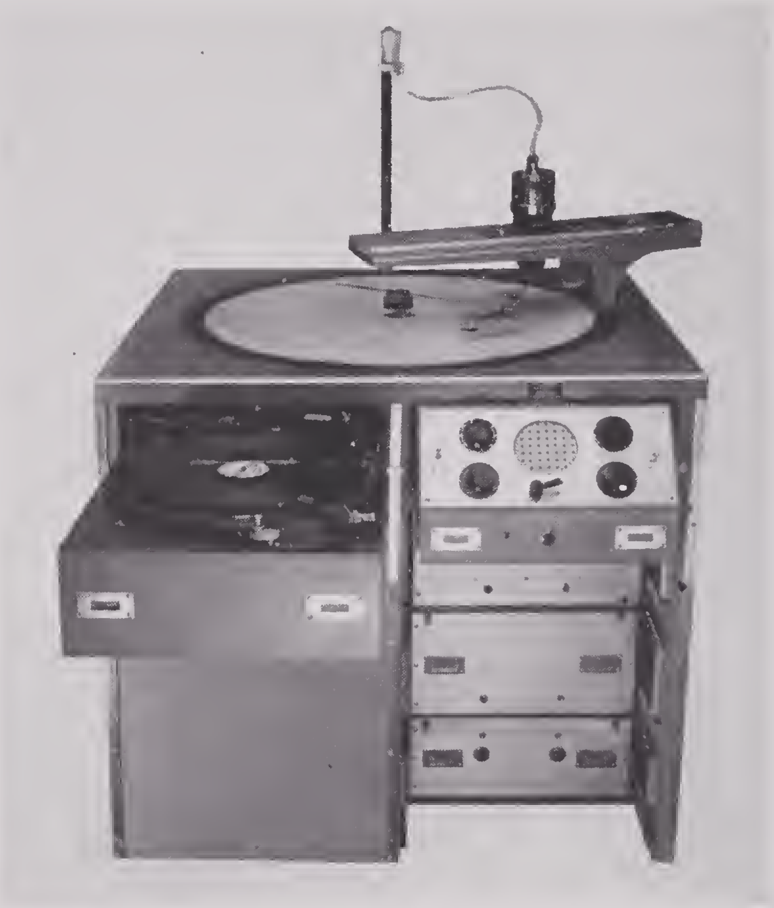


FIGURE 1. Directional radio sono buoy trainer.

12.1 INTRODUCTION

Early in the development of the DRSB, it was apparent that the use of aircraft and the expenditure of considerable numbers of operating DRSB units would be required if no shore-based training could be provided. On the other hand, if such training could be made sufficiently realistic, it was believed that one or two checkoff flights using standard equipment would suffice for most of the operating crews.

The DRSB itself is a means of picking up submarine sounds on a floating rotating sonar hydrophone and transmitting the sounds by radio to an aircraft crew. For a complete understanding of the trainer developed to prepare aircraft personnel to use this device, it is necessary that the principles of operation of the DRSB be understood, particularly the method of transmitting bearing information from the buoy to the receiver. The reader is therefore referred to Division 6, Volume 14, Chapter 9.

12.2 GENERAL DESCRIPTION

Figure 1 shows the main unit of the DRSB trainer, which contains the electronic sound generator for supplying target propeller noise. On one side of the unit is a turntable for introducing recorded water noise. The top of the unit carries a plotting board on which the target submarine is represented by a crab. Through the controls on the instrument panel, this crab may be set to move on any course over the plotting board and at any of six speeds (2, 3, 4, 5, 7, or 9 knots) tracing its own course with a pencil stylus.

A synchro and potentiometer arrangement in the center of the plotting board, representing buoy No. 1, is mechanically connected to the moving crab or target. As the target moves, the synchro alters the propeller noise signals for bearing, and the potentiometer alters them for range. The resulting radio signals sent out on buoy No. 1 transmitter thus correctly simulate the output of a DRSB, providing means for determining the bearing and range of the target with respect to the buoy. The generated propeller sounds closely resemble the sounds heard from an actual submarine over the rotating directional hydrophone of a DRSB, and the recording provides a realistic background of water noise.

A second synchro and potentiometer arrangement, representing buoy No. 2, is mounted on a movable bridge over the plotting board. It may be placed in any direction and at any distance from 0 to 6,000 scale yd from buoy No. 1. This second buoy is also connected mechanically to the target crab, and its signals are sent out on a second transmitter adjusted to transmit on a different frequency from that of the first buoy. The two buoys may be operated simultaneously for practicing triangulation if desired.

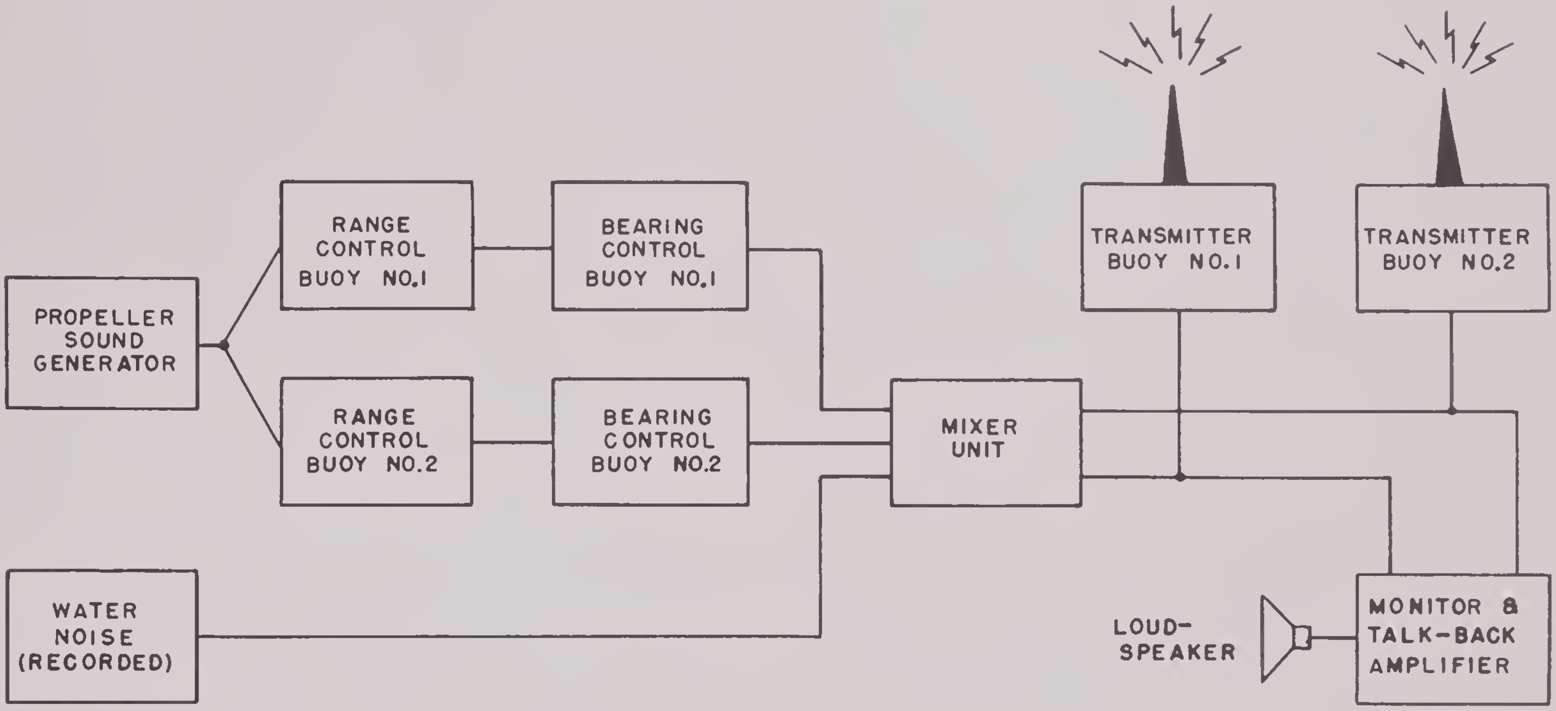


FIGURE 2. Block diagram of DRSB trainer.

Figure 2 is a block diagram showing the relationship of the different parts of the system, and Figure 3 is a detailed diagram.

The radio signal transmitted is virtually the same as that transmitted by the working DRSB. It is a frequency-modulated carrier of around 70 mc, modulated to a maximum deviation of plus or minus 75 kc with an audio bandwidth of about 100 to 8,000 c. The carrier frequency is also deviated from its normal value to transmit directional information.

The target-sound level may be adjusted to provide various degrees of sound output from the target; that is, it can represent a noisy or a quiet submarine. The water-noise level may also be adjusted to represent various sea conditions.

A loudspeaker is mounted in the control panel for monitoring by the instructor or a group of students. A switch permits monitoring either buoy No. 1 or No. 2. A press-to-talk switch converts the loudspeaker into a microphone, so put of either buoy No. 1 or buoy No. 2, or the output of any of the twelve student receivers. He can also talk to any student over the intercommunication system circuit. When the student wants to initiate a conversation, he operates a signal light on the instructor's repeater unit by pushing a button at the operator's station.

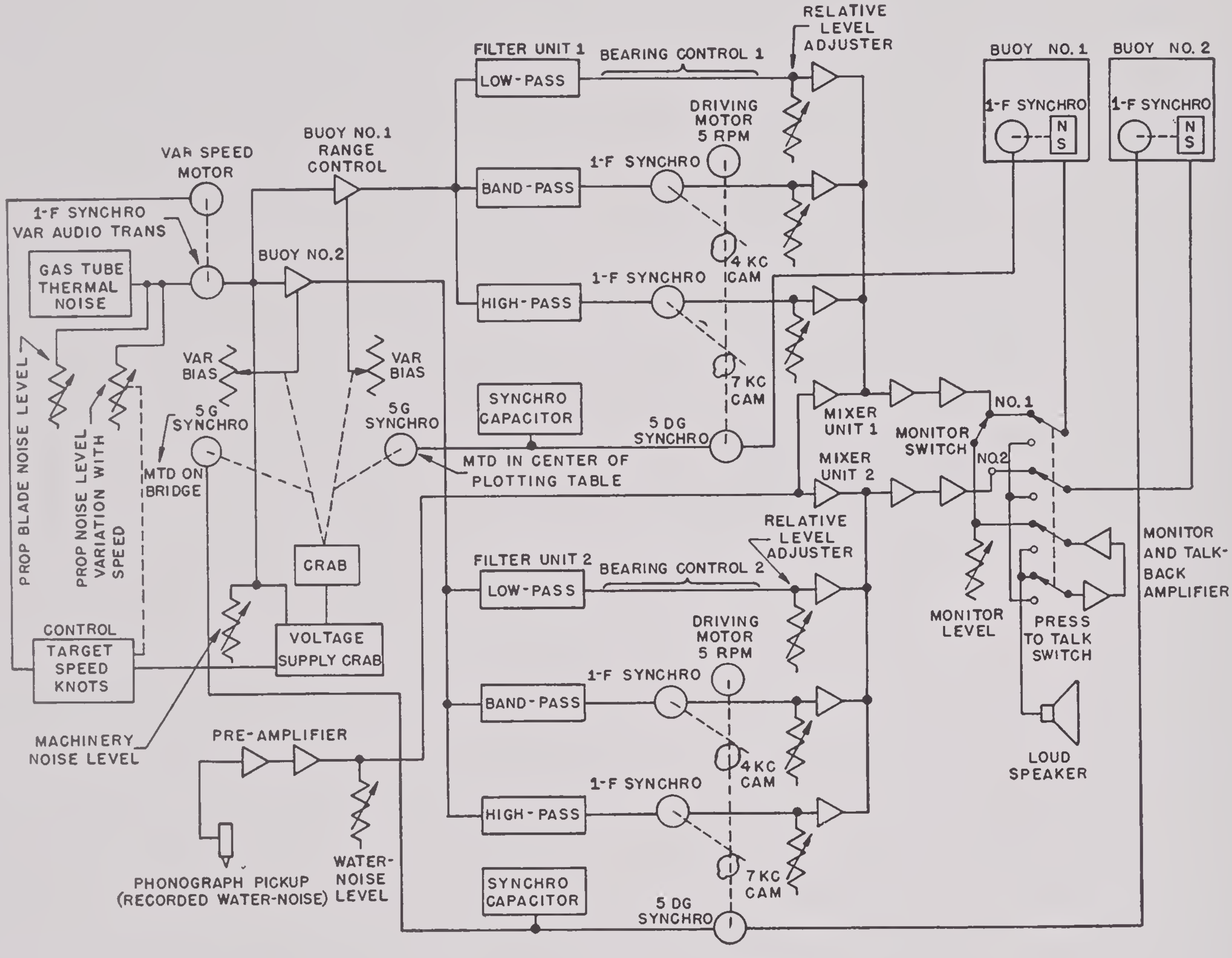

RELATIVE LEVEL ADJUSTER
FILTER UNIT 1
BEARING CONTROL 1
LOW-PASS
BUOY NO. 1
BUOY NO. 2
1-F SYNCHRO
N
S
1-F SYNCHRO
N
S
DRIVING MOTOR 5 RPM
BUOY NO. 1 RANGE CONTROL
VAR SPEED MOTOR
1-F SYNCHRO
BAND-PASS
1-F SYNCHRO VAR AUDIO TRANS
GAS TUBE THERMAL NOISE
BUOY NO. 2
4 KC CAM
1-F SYNCHRO
HIGH-PASS
VAR BIAS
VAR BIAS
7 KC CAM
5 G SYNCHRO
5 G SYNCHRO
SYNCHRO CAPACITOR
5 DG SYNCHRO
MIXER UNIT 1
NO. 1
MONITOR SWITCH
NO. 2
MIXER UNIT 2
MTD ON BRIDGE
MTD IN CENTER OF PLOTTING TABLE
PROP BLADE NOISE LEVEL
PROP NOISE LEVEL VARIATION WITH SPEED
RELATIVE LEVEL ADJUSTER
MONITOR AND TALK-BACK AMPLIFIER
CRAB
FILTER UNIT 2
BEARING CONTROL 2
LOW-PASS
CONTROL
TARGET SPEED KNOTS
VOLTAGE SUPPLY CRAB
DRIVING MOTOR 5 RPM
MONITOR LEVEL
PRESS TO TALK SWITCH
1-F SYNCHRO
BAND-PASS
MACHINERY NOISE LEVEL
PRE-AMPLIFIER
4 KC CAM
LOUD SPEAKER
1-F SYNCHRO
HIGH-PASS
PHONOGRAPH PICKUP (RECORDED WATER-NOISE)
WATER-NOISE LEVEL
SYNCHRO CAPACITOR
7 KC CAM
5 DG SYNCHRO

FIGURE 3. Detailed diagram of DRSB trainer.

connected that the instructor may talk through both transmitters simultaneously. This permits him to give necessary instructions over the air to all students tuned to either buoy.

The instructor's repeater unit, shown in Figure 4, is usually mounted on a desk adjacent to the trainer. Its dials give the instructor continuous readings on the range and bearing of the target from both buoys. By pressing the appropriate pushbutton on this unit, the instructor can monitor with earphones the out-

12.3 DETAILED DESCRIPTION OF OPERATION

SIGNAL SIMULATOR SYSTEM

The noise source for the submarine propeller beats is a gas tube generating thermal noise of sonic frequencies (see Figure 3). This output is fed through a level adjustment to the stator windings of a 1-F synchro used as a variable transformer. Each revolution of the rotor of the 1-F develops two noise nodes simulating propeller beats. The rotor is turned by a variable speed motor, which is controlled by the same speed control as the target crab motor. The rotor speed is adjusted to give propeller beats at the rate of 25 for each knot of submarine speed. The target sound output is then split into two identical channels for buoy No. 1 and buoy No. 2. After that the propeller beats are fed through a variable gain amplifier where the intensity of the signal is varied so that as the range increases the intensity of the signal decreases accordingly. The change in level is approximately 6 db per distance doubled, thus accurately representing average operating conditions. The signal is next fed into a filter unit where it is divided into three frequency channels by means of a low-pass, a band-pass, and a high-pass filter. The low frequency channel is not further altered. The band-pass channel (around 4,000 c) is altered (by the synchro and the cams) to correspond to the beam pattern for middle frequencies. The high-pass channel is likewise altered. Each channel is then fed through a potentiometer where the relative levels of the three channels may be adjusted to simulate the actual buoy noises for each frequency band.

The output of these three channels is fed to the mixer unit, where it is combined with the recorded water noise. The water-noise level can be varied independently to represent different sea states. This mixed signal of water noise and propeller beats is then amplified and fed into the buoy transmitter.

SYNCHRO SYSTEMS

For each buoy channel there is a synchro system which changes the target signal according to bearing. This change takes into account two factors: the constant turning of the hydrophone and the change in bearing caused by movement of the target.

To simulate the turning of the hydrophone, there is a small motor rotating at 5 rpm which drives a pair of cams. Followers on these cams alter the position of the rotors in the 1-F synchros, which act as variable-gain audio transformers for the 4,000 and 7,000-c portions of the signal, thus simulating the directional pattern of the hydrophone. This motor drives a 5-DG synchro, which is a differential generator. The 5-DG in turn drives a 1-F synchro located in the transmitter. The 1-F synchro carries a permanent magnet which, in rotating, turns a small compass-controlled condenser in the transmitter. This condenser varies in capacity with rotation and changes the mean carrier frequency of the transmitter just as is done in the DRSB. An early development model DRSB compass condenser is, in fact, used for this purpose. This sequence of operations is adjusted so that when the target is, for example, on 000 degree true from buoy No. 1, the audio signal will "beam" when the receiver direction indicator is going through bearing 000 degree, or north. In reception, action of the receiver is identical with that of an actual operating DRSB signal.

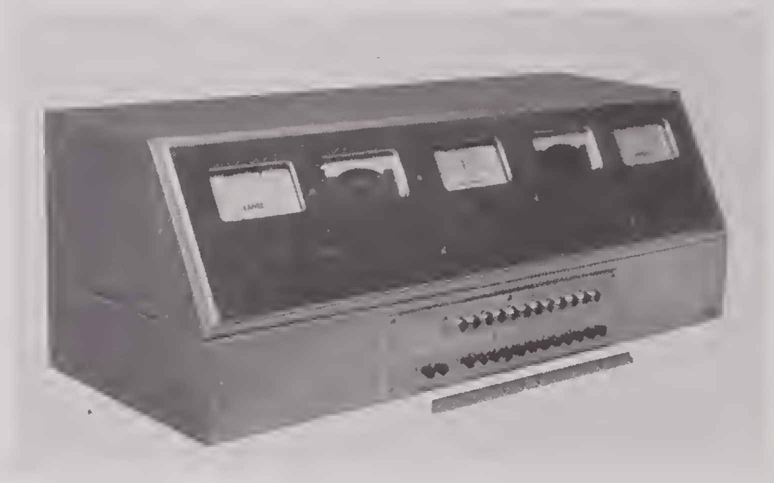


FIGURE 4. Instructor's repeater for DRSB trainer.

When the target crab is moved to a different bearing, the 5-G synchro to which it is mechanically connected is rotated through a corresponding angle. This synchro voltage is fed to the 5-DG. The changed signal output from the 5-DG will, during the angular movement of the target, be equal to its shaft speed of 5 rpm plus or minus the angular speed of the target around the buoy. The 1-F synchro rotating the magnet together with the condenser as indicated above and following this changing synchro voltage will speed up or slow down, thereby maintaining the proper phase relation with respect to the simulated hydrophone direction beam. Therefore, the transmitter signal will always give the hydrophone audio beam at the instant when the direction indicator is at the bearing of the target crab from the buoy.

MONITOR SYSTEM

Amplifier and Talk-Back. The monitor switch on the trainer is a single-pole, double-throw switch which enables the instructor to monitor, by means of the loudspeaker, the audio signal fed into either transmitter. As the combined target signal and water-noise signal comes from the mixer it is fed not only into the transmitter but also through a potentiometer which adjusts the level of the signal and then on through an implifier into the loudspeaker. When the press-to-talk switch is pressed down, it disconnects the signal into the transmitter and connects the speaker as a microphone to the input of the amplifier. The output of the amplifier is then switched to both buoy transmitters. The instructor's words go through the amplifier and into the transmitters, where they are sent out to the receivers.

Play-Back. The recorded water noise goes through the phonograph preamplifier and on through the potentiometer, which provides an adjustment for the water-noise level. From here the noise is fed into both mixer units.

The alternating current on the turntable is not connected to the master switch, so that the turntable operates independently of the master switch.

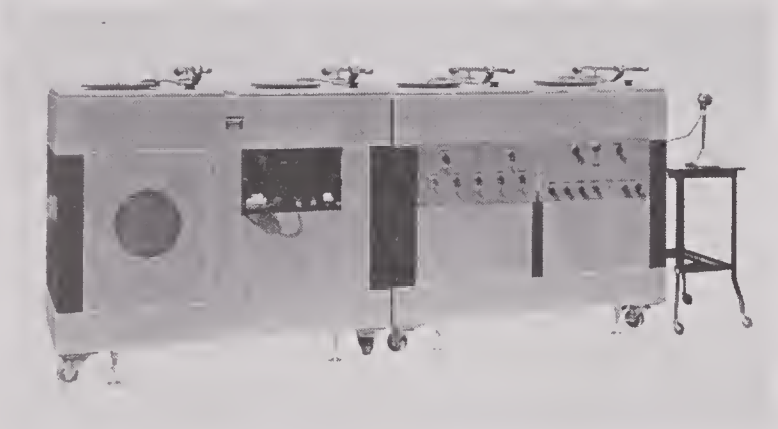


FIGURE 5. Expendable radio sono buoy trainer.

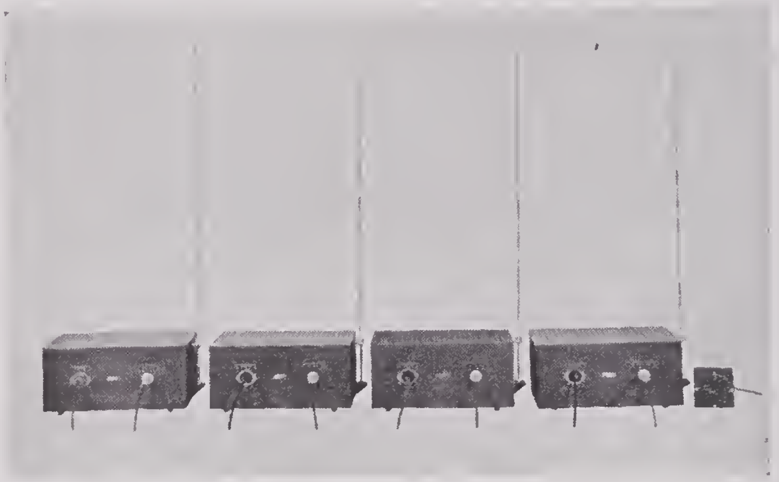


FIGURE 6. Transmitters for ERSB trainer.

Expendable Radio Sono Buoy Trainer

The expendable radio sono buoy trainer [ERSB], developed by CUDWR-NLL, consists of a bank of four turntables and four reproducers to simulate from recordings the sounds of submarines received by radio from ERSB's laid down in patterns on the ocean surface. Figures 5 and 6 give a general idea of how the equipment was set up. For a complete description of the ERSB itself, see Division 6, Volume 14, Chapter 9.

Chapter 13

MISCELLANEOUS TRAINERS AND DEMONSTRATORS

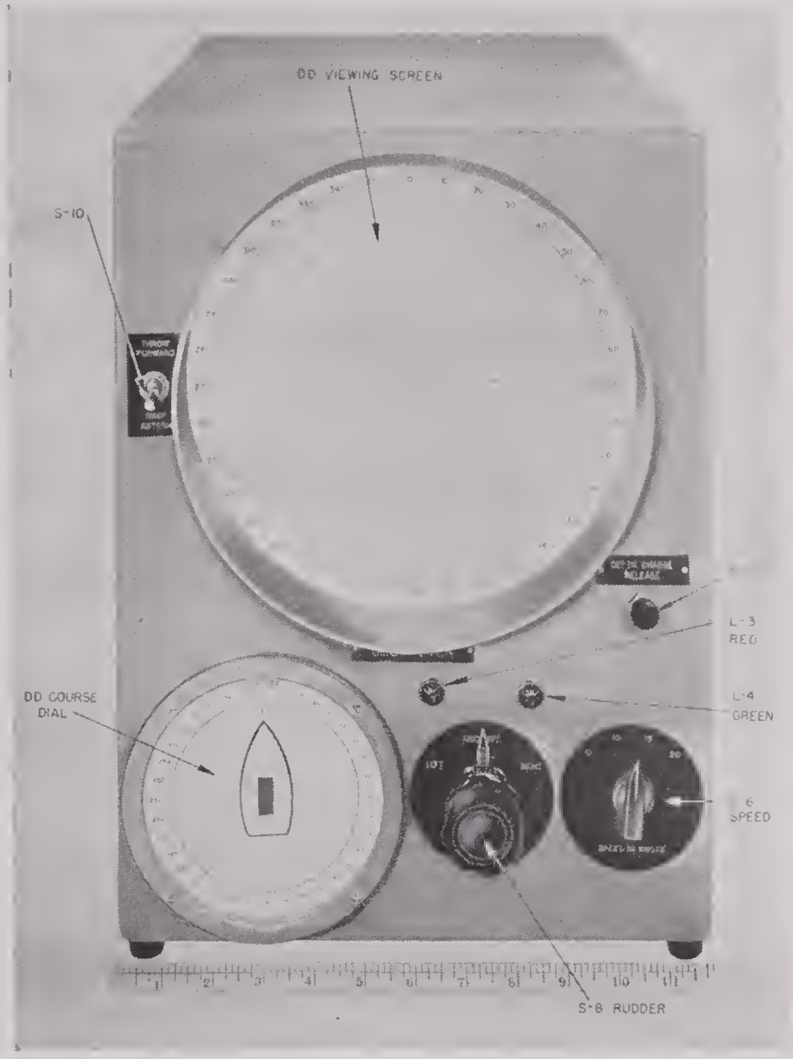


FIGURE 1. Primary conning teacher, conning position.

Primary Conning Teacher

The primary conning teacher [PCT] is a device for training conning officers to use information obtained from echo-ranging equipment to plot the course of a surface vessel throughout an attack run upon a submarine target. At one end of the machine, target range and bearing information are optically presented on a screen at realistic intervals, and engine and rudder controls are provided to enable the conning officer trainee to change the speed and course of his ship accordingly. In a second control station at the opposite end of the machine is a "submarine commander" who controls the speed and course of the simulated submarine target. One model of the conning teacher, designated model B1, simulates the action of a fast ship with a comparatively large turning circle, whereas another version, model B2, simulates a slower ship with a small turning circle. The complete instrument weighs 70 lb and is contained in a metal cabinet measuring 12x16x23 in. It operates from a 110-v, 60-c power supply and requires a current of approximately 3 amperes. The PCT was originally built at the University of Pennsylvania and later was modified and improved by UCDWR.

THE USUAL ATTACK teacher operation was too complex to provide elementary training in methods of plotting own-ship's course. The development of the primary conning teacher, however, made it possible to hold extensive drills in plotting, with continuous increase in the level of difficulty. Students could thus be brought to the point where they could plot efficiently when using attack teacher information and during their sea training.

Most of the attack teachers in use during World War II were not equipped to provide *bearing deviation indicator* [BDI] bearings. The conning teacher, by furnishing accurate ranges and bearings at regular intervals, simulates BDI conditions with considerable fidelity and thus also gives students excellent training in this phase of interpreting conning instructions.

The principles of operation in Models B1 and B2 of the conning teacher are the same and are described below.

13.1 PRINCIPLES OF OPERATION

The conning officer trainee is seated at one end of the instrument and imagines his ship to be at the center of the screen on the panel before him (see Figure 1). The range (2,000-yd maximum) and bearing of the submarine target are indicated to him by a small round light spot which appears intermittently on the screen. The frequency with which the spot appears is approximately that at which he could expect to obtain information from a good sound operator. Likewise on the panel are engine and rudder controls with which the conning officer can change the speed and course of his ship. Delays are incorporated in the rudder control to simulate the lag in the ship's response to the helm; the rate of turning is also a function of the ship's speed. Turning rates were selected so as to be appropriate for an average ship of the class which the instrument is intended to represent. Ship's speed is controllable without time lag.

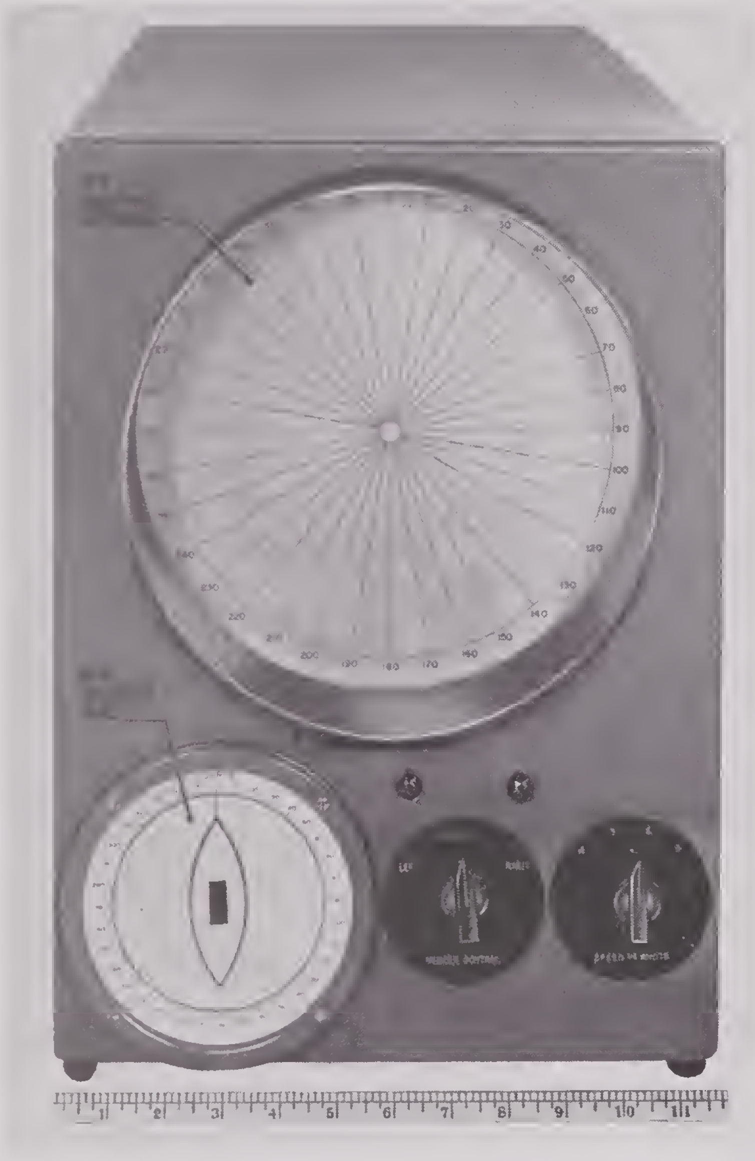


FIGURE 2. Primary conning teacher, submarine position.

When the device is in normal use as an elementary conning trainer, a problem-setter occupies the instructor's or submarine position (see Figure 2). He imagines his ship (the submarine) to be at the center of his screen on the course indicated by the course dial. A continuous light spot on the submarine screen here portrays the movement of the destroyer with respect to the submarine and is calibrated for bearing but not for range. Controls for changing the speed and course of the submarine are provided and also appropriate delays and turning rates.

At the beginning of each run the problem-setter sets the light spot and thereafter provides the conning trainee with additional information in accordance with the desired exercise. The exercises can vary from the simple case in which the trainee is given a constant speed and course for the submarine to exercises where the problem-setter regards himself as a submarine commander and employs all the evasive tricks at his command to avoid destruction.

It is possible to apply various criteria of judgment in evaluating an attack. For example, the scoring of a mousetrap problem might be made on the ability of the conning officer to maneuver his ship so as to be on the correct bearing at the instant of "fire," or, in another case, the conning officer might be held responsible for the *time* of fire as well as for the correct ship's course.

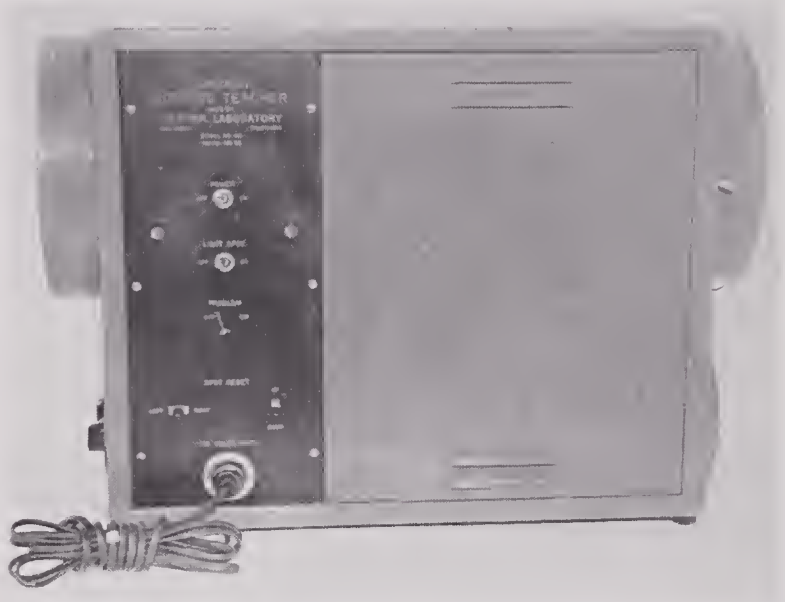


FIGURE 3. Primary conning teacher, side view showing auxiliary control panel.

With the conning teacher it is possible to provide exercises to which such different criteria may be applied. These exercises include

SPOT RESET ↕UP-DOWN↕
SPOT RESET ↕RIGHT-LEFT↕
R-5 1000
R-6 150
R-7 1500
POTENTIOMETER ON SS STEERING MOTOR
P-2
SS SPEED
P-1
POTENTIOMETER ON DD STEERING MOTOR
DD SPEED
T-1
SEE NOTE-1
DD STEERING MOTOR
M-1
SEE NOTE 3
SS STEERING MOTOR
M-2
0.28 RPM
PROBLEM ↕ON-OFF↕
R-1
R-2
R-3
SEE NOTE-2
R-4 SEE NOTE 2
110 V 60~
POWER ON-OFF
5-AMP FUSES
SHUTTER MOTOR
M-3 4 RPM
WATTHOUR METER HORIZONTAL MOTION W-2
WATTHOUR METER VERTICAL MOTION W-1
APPROX 0.060
R-14
APPROX 0.045
R-15
L-2
L-1
LIGHT SOURCES
T-3
LIGHT SPOT ON-OFF
CURRENT TRANSFORMER T-2
RECTIFIER FOR CHARGING CONDENSERS IN TIME DELAY CIRCUITS
V-4 117Z6
C-7 4 μf
F-1
F-2
F-3
RED L-3
F-4
GREEN L-4
F-5
DESTROYER STEERING CONTROL RELAYS
R-9 0.33 MEG
R-8 1 MEG
AMIDSHIPS
LEFT
RIGHT
FULL
SLOW
DD RUDDER CONTROL
TIME DELAY CONTROL TUBE
V-1 117L7
C-4 10 μf
R-16 1500
C-1 4 μf
F-6
F-7
F-8
RED L-5
F-9
GREEN L-6
F-10
SUBMARINE STEERING CONTROL RELAYS
R-11 0.47 MEG
R-10 1.35 MEG
SS RUDDER CONTROL
V-2 117L7
C-5 10 μf
R-17 1500
C-2 4 μf
F-11
DEPTH CHARGE RELEASE
L-7
R-13 1.35 MEG
R-12 1.80 MEG
THROW FORWARD
DROP ASTERN
F-12
F-13
V-3 117L7
C-6 10 μf
C-3 4 μf
R-18 1500

NOTES

1 MODEL B1 WIRING AS SHOWN
MODEL B2 WIRING USE TAPS 7-8-
INSTEAD OF TAPS 7-9-10-11

2 MODEL B1 R-1 200 OHMS
R-2 350 OHMS
R-3 OPEN
R-4 100 OHMS

MODEL B2 R-1 150 OHMS
R-2 200 OHMS
R-3 1000 OHMS
R-4 75 OHMS

3 MODEL B1 M-1 IS 0.28 RPM
MODEL B2 M-1 IS 0.70 RPM

FIGURE 4. Electrical schematic for the primary conning teacher.

preliminary and advanced plotting instruction, depth charge attack (with BDI) on straight-course submarine, forward thrower attack (with BDI) on straight-course submarine, depth charge attack (with BDI) on maneuvering submarine, and forward thrower attack (with BDI) on maneuvering submarine.

13.2 GENERAL DESCRIPTION

The primary conning teacher is shown in Figure 3. A complete electrical schematic[1] for the teacher is given in Figure 4.

Optical Unit. The target spots for the destroyer and submarine screens are obtained by the light from a Mazda No. 1129 bulb passing through an 0.008-in. diameter hole in a thin diaphragm in the lamp housing, through a double convex lens, and on to a movable front-surfaced mirror from which it is reflected onto the screen. Each screen consists of a scale printed on translucent paper secured between two Lucite disks. The scales are adjustable to permit alignment of the destroyer and the submarine scales independently. The light sources are energized from transformer T-3 when the power and light switches are on.

The mirrors are driven by two watt-hour meters W-1 and W-2, the former serving to rotate the mirrors about a horizontal axis and move the light spots vertically or North-South, and the latter to tilt the mirrors about their vertical axis and thus move the light spots horizontally or East-West. The voltage coil of W-1 is energized by a variable voltage which is always proportional to the North-South component of the relative motion of the destroyer and the submarine. Similarly, the voltage on W-2 is proportional to the East-West component of the relative motion.

Resistance potentiometers P-1 and P-2 are mounted on the steering motors M-1 and M-2. Each of the potentiometers is center-tapped and is provided with two sliding contacts whose position is controlled by two cams mounted on the motor shaft. The cams are so shaped and oriented on the shaft that when the motor is turned to a given true course as indicated by the course dial the voltage between the center tap and the front (as viewed from the shaft end of the motor) contact is proportional to the East-West component of the ship's motion on that course at the selected speed, whereas the voltage between the center tap and the rear contact is proportional to the North-South component of the motion.

Destroyer Steering Motor Circuit. The destroyer steering motor M-1 is a reversible, single-phase, shaded-pole motor. Speed changes are effected by inserting resistance in series with the shading coil windings. The rate of change of course (rate of turning of the motor) is a function of both the degree of rudder and the ship's speed. The direction and rate of turning are both controlled by the DD control switch. A 12-sec delay period is provided by the time-delay tube V-1.

Submarine Steering Motor Circuit. The submarine steering motor M-2 is controlled by the SS rudder control switch. Only full rudder is provided. The time-delay circuit, including V-2, is similar to that for the destroyer steering motor circuit, and provides a 15-sec delay going into a turn and a 5-sec. delay coming out of a turn.

Barrage Release Circuit. When the depth charge release switch is momentarily closed, relay F-11 operates and signal lamp L-7 is lighted.

The length of the time interval is 14.5 sec for the throw forward position, while for the drop astern position the time delay is 19 sec.

13.3 CONCLUSION

From all reports, the conning teacher satisfactorily met the need for a device to provide preliminary training for conning officers in antisubmarine attack methods. It was particularly well adapted to instruction in conning attacks with BDI. The fact that each performance by the conning officer could be easily scored provided a convenient check on the progress of the officer. One hundred and four units were procured by the Navy from the Sangamo Electric Company.

Magnetic Ocean Demonstrator

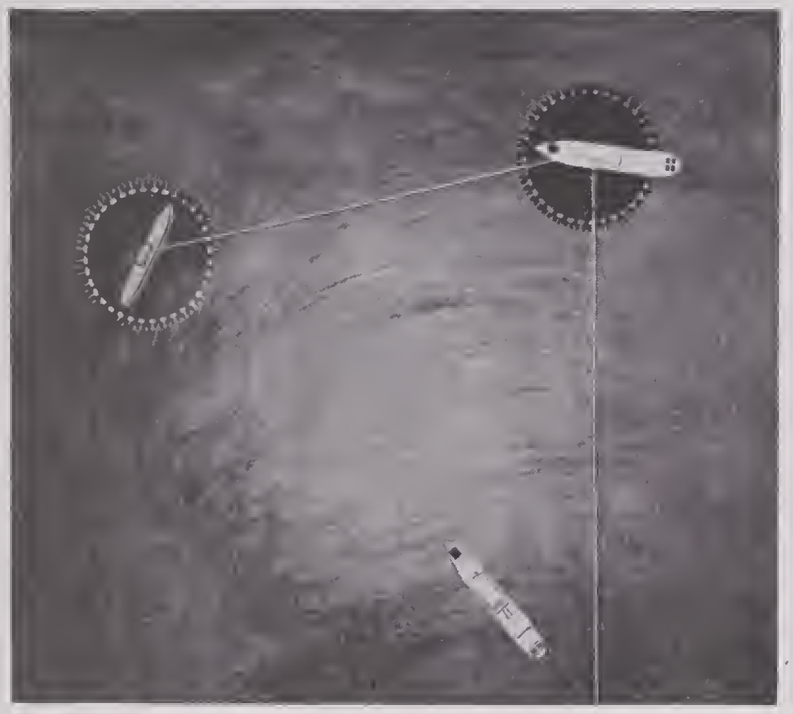


FIGURE 5. Magnetic ocean demonstrator.

The magnetic ocean demonstrator is a classroom visual aid designed to illustrate the role of relative motion in various antisubmarine warfare situations. It consists of two 8-in. models of ASW vessels and one 6-in. model of a submarine mounted by means of magnets on a vertical iron sheet painted black. The submarine and one ASW vessel are each attached to 8-in. relative bearing disks and are maneuvered in conjunction with the disks. The submarine's periscope and the forward part of the ASW ship's bridge, both mounted over the center of the respective disks, are attached by a taut string which demonstrates relative bearing and target angle. The unattached ASW vessel is likewise maneuverable and serves to give practice in bearing estimation. The magnetic ocean demonstrator was developed by UCDWR.

It was a short time after the initiation of a lecture analysis program by UCDWR at WCSS that it was found that one of the greatest needs was effective visual aids. Among these was some type of simple demonstration for illustrating relative bearing and target angles and lead angle corrections in various kinds of antisubmarine attack situations. After tryouts of a number of models for this purpose, it was decided to use 8-in. antisubmarine warfare vessels and 6-in. submarine models, mounted by means of magnets on a 4x4 ft upright sheet.

Although the visual aids project was initiated primarily for the officers' course, "magnetic sea" units were constructed not only for the officers' schools, but also for the operators' schools.

13.1 DESCRIPTION

The submarine is so mounted that its periscope is in the center of the disk, and the ASW vessel is mounted so that the forward part of the bridge is in the center of the disk.

A string, held taut by a small lead sinker runs from the periscope of the submarine (where it is secured by a bowline to allow it to rotate freely) through an eye on the forward part of the ASW vessel's bridge. (Figure 5.) This arrangement results in showing at all times relative bearing and target angle of submarine. A forward-throwing rack and depth charges mounted on each ship and painted black facilitate instructions on lead angle corrections due to difference between sonar bearing and bearing from depth charges or forward throwers.

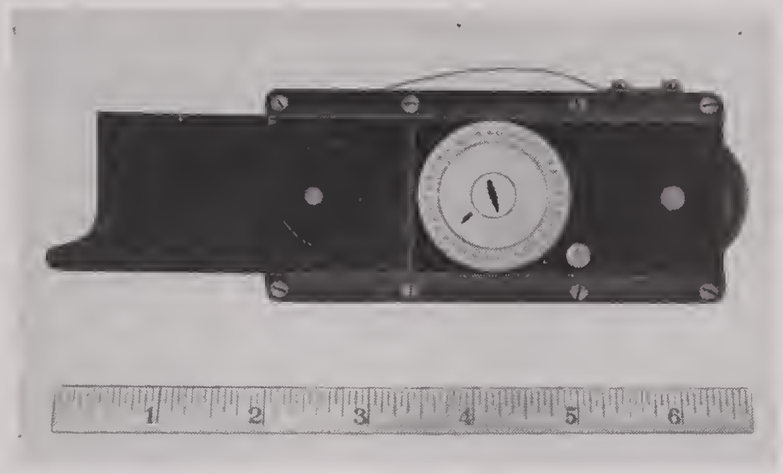


FIGURE 6. Relative bearing animated trainer.

Relative Bearing Animated Trainer

The relative bearing animated trainer [RBAT], developed by CUDWR-NLL, is a lantern slide representing a relative bearing scale with parts which can be moved while the slide is in the projector. An image of a ship appears in the center and another image of a target ship is so placed that it can be rotated around the central ship. A sliding shutter is used to conceal the relative bearing scale while a problem is set and students make a relative bearing estimation. The shutter is then withdrawn and the correct answer read.

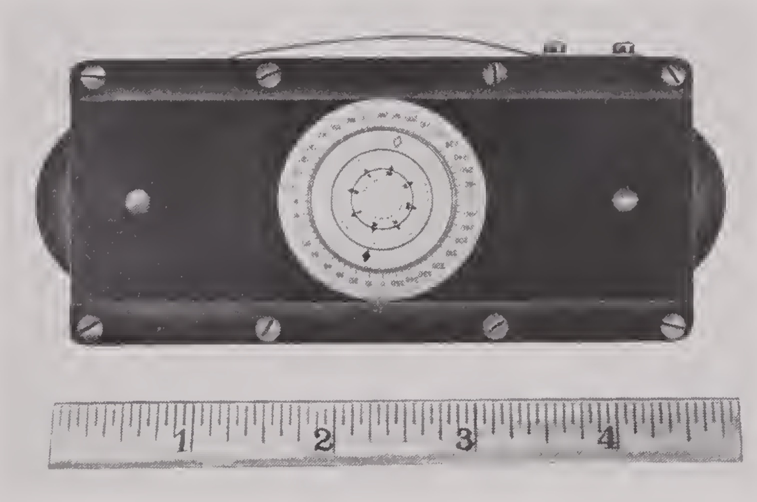


FIGURE 7. Bearing indicator animated trainer.

Bearing Indicator Animated Trainer

The bearing indicator animated trainer [BIAT],[3] *developed by CUDWR-NLL, is a lantern slide representing the bearing repeater dials of a sonar stack, with controls which enable the instructor to vary the readings while the slide is in the projector. It is used to project a variable image on a screen in classroom demonstrations of search, sweeping target, and other sonar operator procedures.*

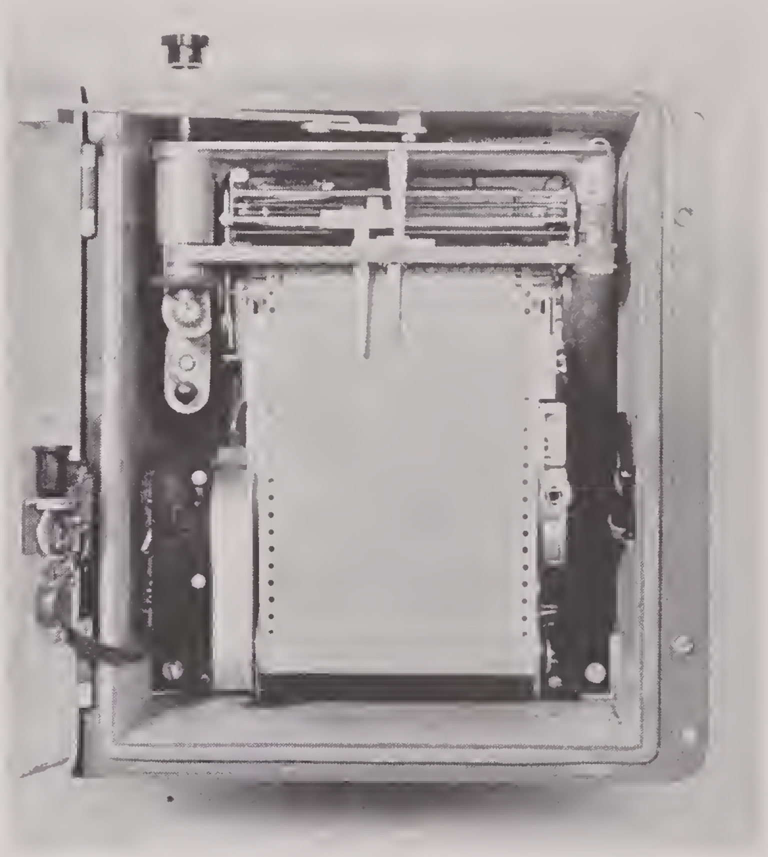


FIGURE 8. OBR front view, cover open to show chart and stylus mechanism.

Operational Bearing Recorder

The operational bearing recorder [OBR], developed by HUSL, is a sound range recorder modified to record both the actual projector bearings and the corresponding bearings called by the sonar student, so that by comparing the two tracers the student may study his errors and evaluate his progress in training under a variety of conditions and with different operating techniques. A servo-synchro mechanism connected to the recorder stylus records the projector bearings. A manually controlled stylus allows simultaneous recording of the bearings called by the sonar operator. The two traces are recorded on wax-coated paper moved at a constant speed by a clock-motor mechanism.

13.5 DESCRIPTION

In order to fill quickly the need for an instrument that could make a graphic record of both actual sonar projector bearings and target bearings called by the sonar operator, a Barber-Coleman recorder already developed as a unit in an attack director was rebuilt to serve as a basis for the new device. In the OBR unit (see Figure 8), the Barber-Coleman recorder is so arranged that the string-driven stylus automatically records actual projector bearing, and a second, tape-driven stylus, operated manually, records called bearings. A sample OBR record is shown in Figure 9. The two traces are displaced about 2 seconds (vertically on the chart) with respect to each other because the points of the two styli cannot be brought closer together with the mechanical arrangement employed.

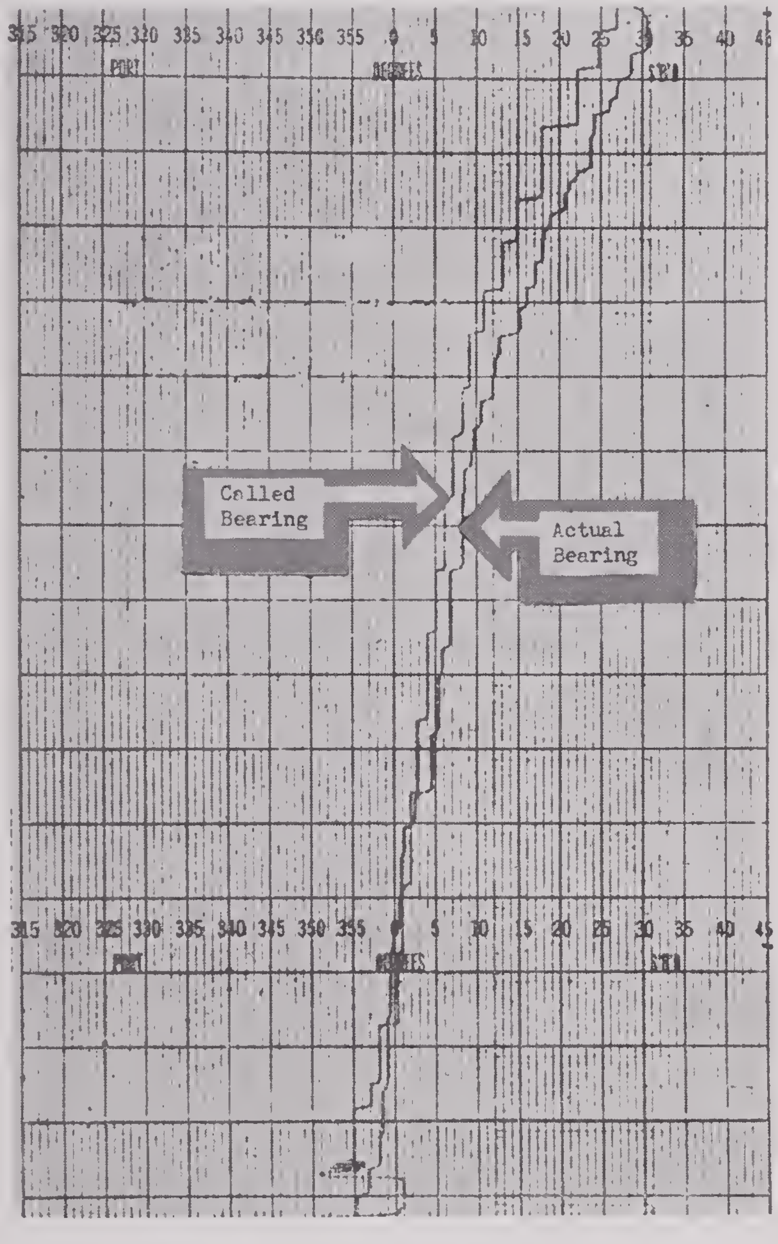


FIGURE 9. OBR record, called bearings obtained from BDI.

To effect this arrangement, the following modifications were made in the original recorder (see Figure 10).

1. The Barber-Coleman recorder was modified to provide a continuous record of *actual projector bearings* by removing the driving motor for the string-driven stylus and extending the drive shaft through the back of the case where it terminated in a slotted disk *a*. A new string-driven stylus *b* that would pass in front of the manually controlled stylus was substituted for the original one, and the tapping solenoid was disconnected so that the new stylus would record continuously.

2. So that *called bearings* might be recorded, the shaft carrying the bevel gear and leading back to the synchro was removed, and the ball-bearing clamping nut on the top of the tape sprocket was replaced by a ¼-in. shaft extending through the top of the case and terminating in a bakelite knob shown at *c*. A felt washer was placed under the knob to prevent water from flowing into the case and to furnish a small amount of friction. When the knob is turned, the continuous driving tape *d*, graduated in degrees of bearing, moves and carries the stylus *e* with it. Stops were provided to limit the back-and-forth motion of the stylus. The index *j* indicates on the tape the bearing being traced by the stylus *e*.

The principal components of the modified recorder are (1) the called-bearing stylus *e* with a knob for driving it; (2) the actual projector-bearing stylus *b* with mechanical connection to its motor drive; and (3) a clock-motor mechanism for moving the paper.

The string-driven stylus *b* is operated through a 5CT synchro from the *maintenance of true bearing* [MTB] system on a 1:1 basis (in degrees). A 110-v, 60-c, two-phase driving motor is geared to give a maximum speed of approximately 10x360 degrees per minute, thus providing an available speed twice as great as ever required.

The synchro *f* and the driving motor *g* with its amplifier are mounted on a plate attached to the recorder case. Removable cover plates provide access to this equipment.

The synchro is geared to a shaft to which the driving motor is also geared through a friction clutch *h*. This clutch is a safety device to prevent stalling of the driving motor when the string-driven stylus reaches the stop at one end or the other of its travel. The shaft terminates in a disk *i* with a pin projecting from its face near the periphery. When the plate on which synchro and driving motor are mounted is fastened in place on the recorder, this pin in disk *i* enters the slot in disk *a*, coupling the string-driven stylus to its driving mechanism.

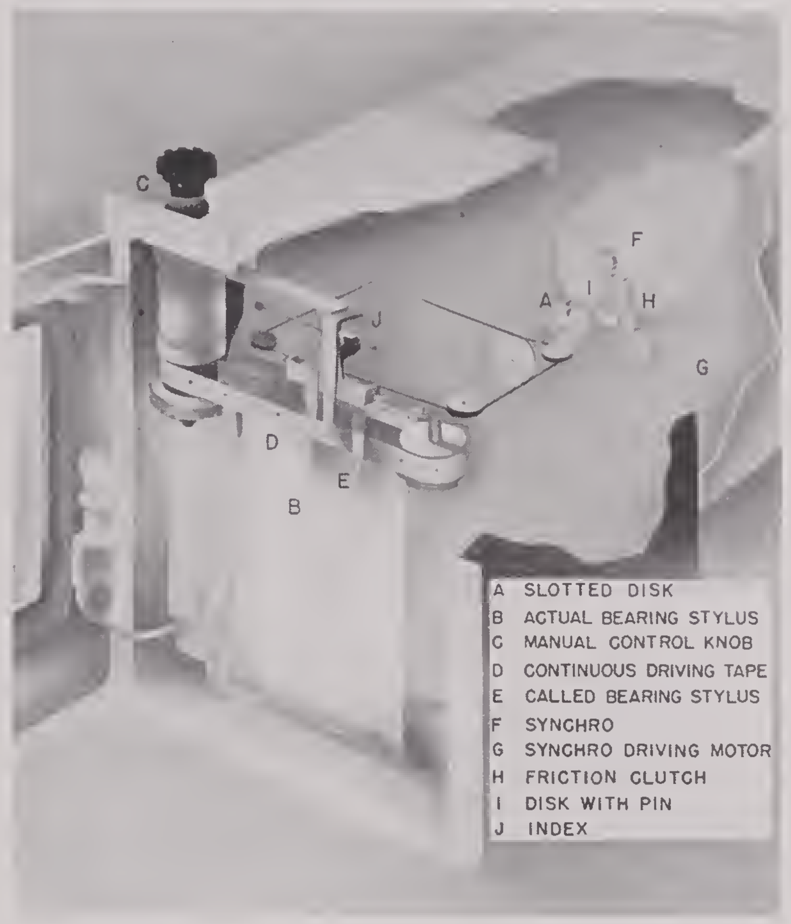


FIGURE 10. Cut-away diagram of OBR, showing modifications in original recorder.

In order that the string-driven stylus may be adjusted to have a 45-degree range on either side of a central zero in each of the four bearing quadrants, a ring attached to the synchro is marked off into eight equal divisions: N, NE, E, SE, S, SW, W, and NW. The top cover plate of the OBR may be swung back on hinges to allow the synchro to be turned manually from quadrant to quadrant as the bearings change.

13.6 RECOMMENDATIONS FOR FUTURE DESIGN

The *operational bearing recorder* [OBR] was built in a short time, largely from material already at hand, in order to permit a quick test of the usefulness of this type of instrument. Experience showed that the following modifications would contribute greatly to the ease of operation and general adaptability of any similar instrument that might be contemplated.

1. The single true-bearing stylus should be replaced by four or more properly marked styli placed 90 scale degrees apart on a tape. The use of multiple styli would eliminate the necessity for manually setting the synchro head as well as the need for travel stops and safety friction clutch.
2. The manual driving system of the called-bearing stylus should be designed so as to eliminate the necessity for resetting the stylus with respect to the tape scale when changing quadrants.
3. Traces of the true-bearing stylus should be made distinguishable from those of the called-bearing stylus, either by color or by the type of lines drawn.
4. The styli should be so designed that the instrumental error, which in the present recorder shows as a time lag of approximately 2 sec between actual bearing and called-bearing traces, would be as small as possible.
5. Any new recorder should be designed to carry a wider record paper than was used in the experimental model. A chart graduated to 120 degrees rather than to the present 90 degrees would prevent the traces from continually running off the edge of the recording paper.
6. A more satisfactory record paper should replace the red wax-coated chart used in the Barber-Coleman recorder, since the wax removed by the styli piles up and interferes with the operation of the driving mechanism. It is also true that the present records are easily marred and cannot be blueprinted. Chemical range recorder paper may be used if the traces

of the styli are not to be distinguished from each other by the use of different colors.

7. Provision should be made for a larger plate or flat surface under the record paper so that notations may be made on the chart as the traces are being drawn.

8. The OBR described in this report was built for use with MTB. For operation with equipment that does not furnish true projector bearing and where only relative bearing and gyro-synchro circuits are available, the CT synchro-controlled servo drive should be replaced by a differential synchro with servo follower. The latter type of drive is to be preferred, in any case, since with it the bearing recorder may be applied to all types of sound gear, whether equipped with MTB or not.

The British bearing recorder AS407 seems to be readily adaptable for use as an operational bearing recorder. With it, the above-listed requirements for improvement over the present OBR should be adequately met.

13.7 CONCLUSION

The operational bearing recorder was satisfactory for its intended purpose. It did not come into common usage as a training device because it was too complicated and because it required resetting of the synchro head and stylus each time the quadrant of operations changed. In addition, the recorder required the full attention of an operator to set in manually the called bearing.

Chapter 14

TRAINERS FOR SUBMARINE SONAR OPERATORS

Trainers developed for the use of student submarine sonar operators closely paralleled those of the antisubmarine warfare [ASW] sonar program. Thus, the primary listening teacher, which was similar to the primary bearing teacher, was a simple device designed for elementary instruction and for rapid quantity production. The advanced listening teacher, completed in the summer of 1944, provided training under more realistic conditions but suffered from the same disadvantage as the advanced bearing teacher, namely, that it required the instructor to devote his entire attention to one student at a time.

References to microfilmed material on these early listening teachers will be found in the bibliography for this chapter. They are not covered here because they were eventually superseded by the more efficient group listening teacher. In this device the problem generator of the advanced listening teacher was adapted for use with ten or more operator stations simultaneously under the direction of one instructor.

This chapter includes first a discussion of the *sound recognition group trainer* [SRGT], which is a direct adaptation of the *echo recognition group trainer* [ERGT] used in ASW sonar operator training. Then follows an account of the *range indicator trainer* [RIT], which is an adjunct of the sound recognition group trainer.

The *noise-level monitor trainer* [NLMT], which is next described, simulates the conditions of using the noise-level monitor at sea. It is followed by a brief reference, illustrated by a photograph, to the *torpedo detection modification* [TDM] trainer. However, no detailed laboratory report was prepared for the TDM trainer.

The *group listening teacher* [GLT], and the monitoring equipment developed for use with sonar gear aboard Navy training barges, are the most complex of the trainers in this group, and are covered last.

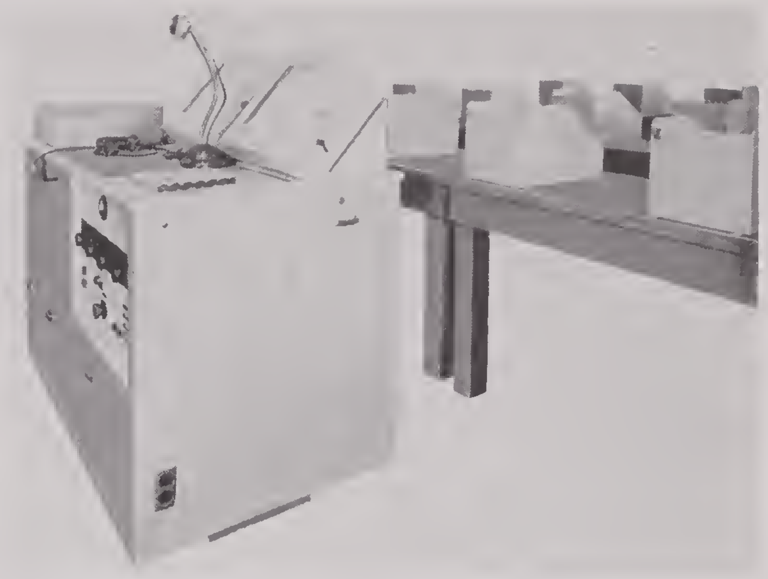


FIGURE 1. Sound recognition group trainer, general arrangement of equipment.

Sound Recognition Group Trainer

The sound recognition group trainer, developed by UCDWR, is a device for reproducing at each of 20 student stations the sounds from a phonograph recording played at an instructor's position, and for registering a permanent record of each student's judgment of what he hears. The student registers his judgment by pressing one of the buttons at the student station. For a variety of realistic operating conditions, the output of the phonograph pickup can be reproduced through either standard JP-type or WCA-type receiver or through a self-contained amplifier with a frequency response flat within 1 db from 50 c to 10 kc.

14.1 INTRODUCTION

Prior to the development of the sound recognition group trainer, the Navy's sound recognition training program was handicapped by the fact that existing teaching equipment required the instructor to devote his entire attention to one student at a time. In 1944, there was an increasingly urgent need to train sonar operators in groups. Existing equipment provided training under realistic conditions, but it could not train operators fast enough to supply the demand. The problem of training operators in groups was therefore undertaken.

The general arrangement of the units in the SRGT is shown in Figure 1, the equipment at the instructor's position in Figure 2, a student's station in Figure 3, and a block diagram of the electric circuits in Figure 4. As indicated in these figures, most of the equipment is mounted in a control console cabinet, which is the instructor's station. The 20 student stations are arranged in three rows, so that the students face the instructor.

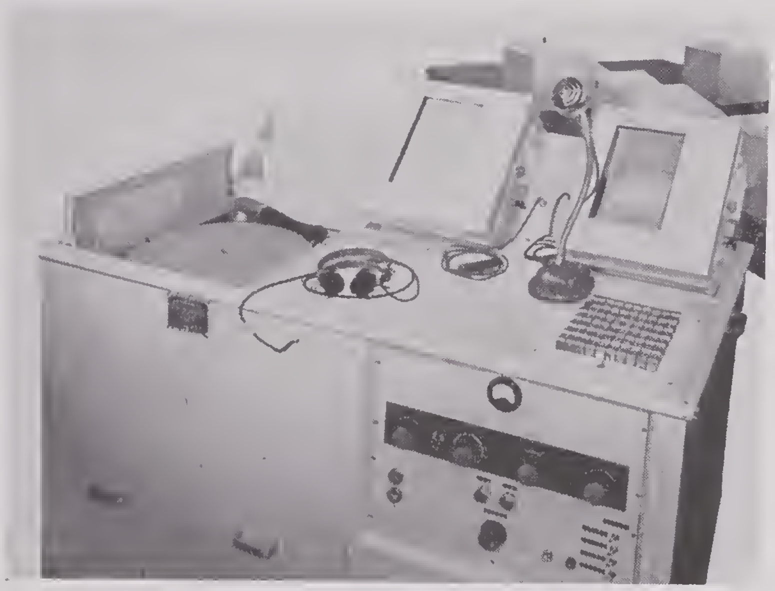


Figure 2. Instructor's position in SRGT.

The recorded sounds are classified and divided into groups, each of which gives the student some practice in some problem of target identification. Before the instructor plays a recording, a code is arranged for the class. For instance, the sound of own-ship's screws may be represented by the number 1 and for convenience, the No. 1 pushbutton may be labeled "screws," as shown in Figure 3. The student listens to the sound recordings over the headphones and records his judgment by pushing one of the buttons on the student station panel. When he pushes the button, the corresponding number appears in facsimile on the paper of one of two monitor recorders at the instructor's station. By looking at the printed record of the students' decisions, the instructor is able to coach the students, and easily grade their performance.

Instructor's Station

The phonograph turntable and pickup accommodate records up to 16 in. in diameter, either 78 or 33⅓ rpm. The various possible operating conditions are chosen by means of the *circuit selector switch* and the *amplifier selector switch*, both on the panel of the "flat" amplifier unit. When the circuit selector switch is in the normal position, the output of the phonograph amplifier is fed directly to the input of one of three units, depending on the position of the amplifier selector switch. The flat amplifier (response uniform within 1 db from 50 c to 10 kc), mounted in the console cabinet, is used when the amplifier selector switch is in the flat position, while either a standard JP-type or a standard WCA-type receiver is used when the switch is in the *J* or *W* positions respectively. The output of the amplifier used is fed through suitable impedance-matching circuits to headphones both at the students' stations and at the instructor's position. The signal level at the headphone circuits is indicated by a decibel meter mounted on the panel of the flat amplifier (some of the recordings include a 1,000-c reference tone for adjusting the overall level). The instructor may talk to the students by means of a microphone provided at the control console.

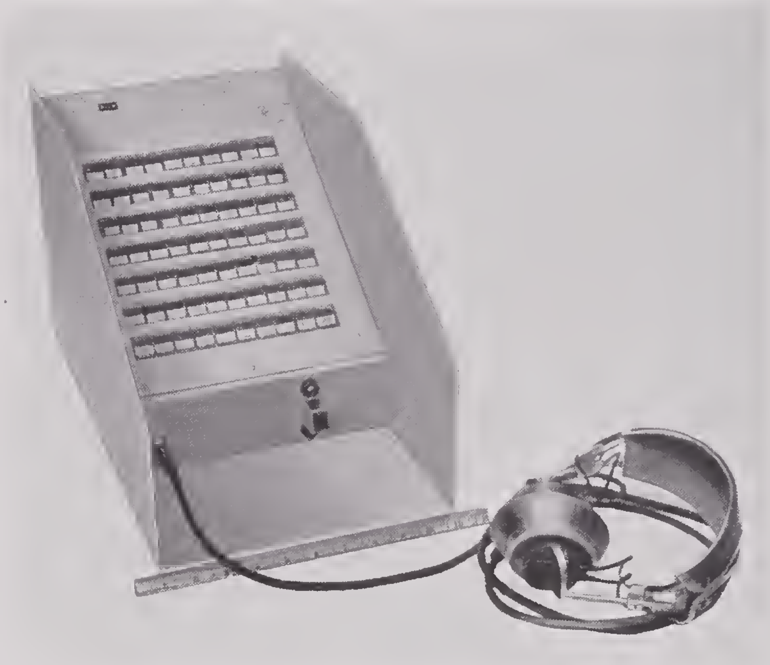


Figure 3. Student station in SRGT.

When the circuit selector switch is in the 70-c high pass, in the keying, or in coding position, a 70-c high-pass filter is connected between the phonograph pickup and the input of whichever amplifier is used. This filter renders inaudible to the students any 70-c or 40-c signal tones included in the recording. The equipment is used with the circuit selector switch in the 70-c high-pass position when it is desired to listen to recordings containing such low-frequency signals without actually employing them for any other purpose. The switch is placed in the keying position when the recordings contain 70-c signals for operating the range indicator trainer, described in the next section. When the switch is in the coding position, the 40-c signals from the phonograph record are used to actuate the monitor recorders.

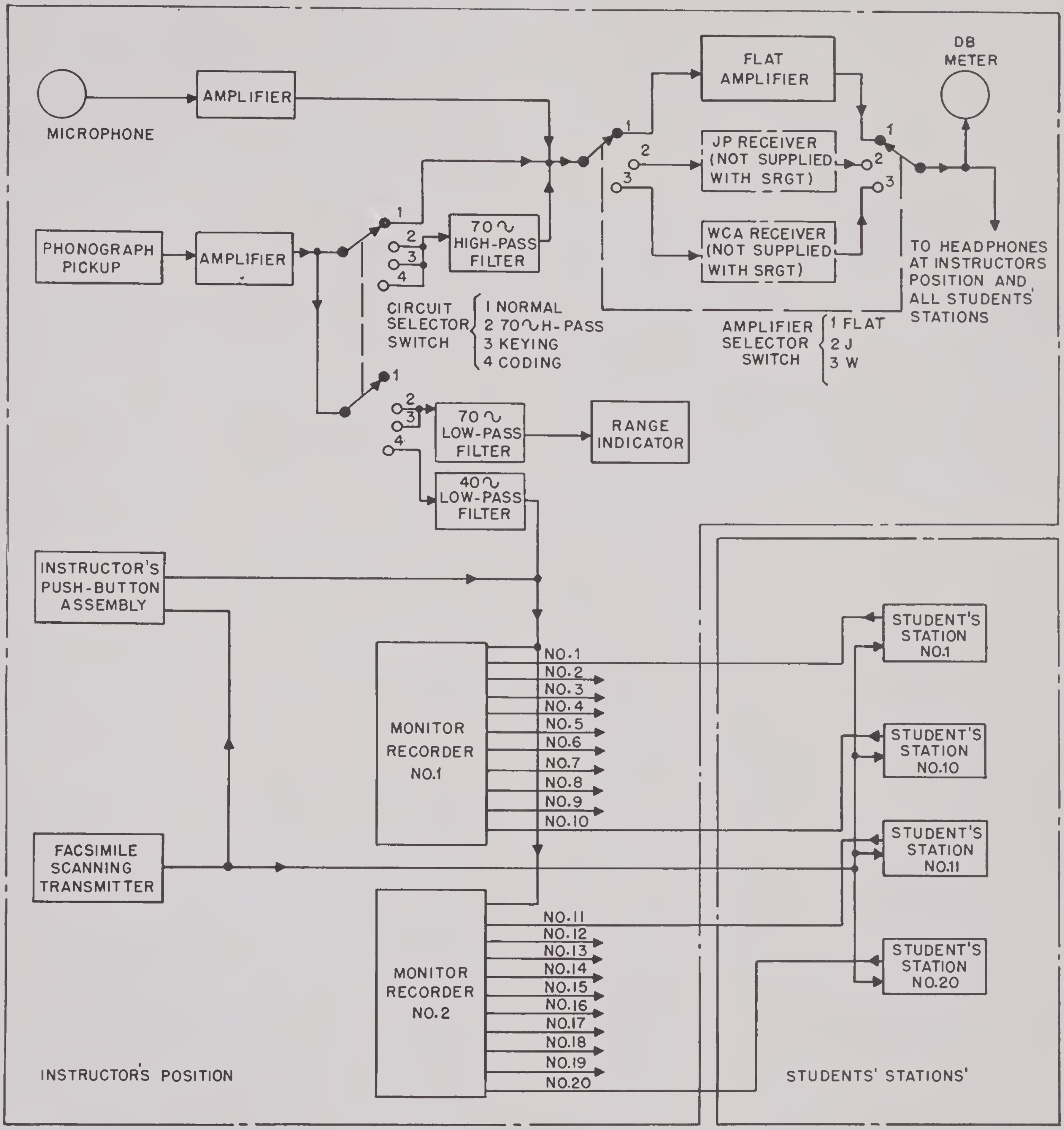

MICROPHONE
AMPLIFIER
PHONOGRAPH PICKUP
AMPLIFIER
70∿ HIGH-PASS FILTER
CIRCUIT SELECTOR SWITCH
1 NORMAL
2 70∿H-PASS
3 KEYING
4 CODING
FLAT AMPLIFIER
JP RECEIVER (NOT SUPPLIED WITH SRGT)
WCA RECEIVER (NOT SUPPLIED WITH SRGT)
DB METER
AMPLIFIER SELECTOR SWITCH
1 FLAT
2 J
3 W
TO HEADPHONES AT INSTRUCTORS POSITION AND ALL STUDENTS' STATIONS
70∿ LOW-PASS FILTER
RANGE INDICATOR
40∿ LOW-PASS FILTER
INSTRUCTOR'S PUSH-BUTTON ASSEMBLY
FACSIMILE SCANNING TRANSMITTER
MONITOR RECORDER NO.1
MONITOR RECORDER NO.2
NO.1
NO.2
NO.3
NO.4
NO.5
NO.6
NO.7
NO.8
NO.9
NO.10
NO.11
NO.12
NO.13
NO.14
NO.15
NO.16
NO.17
NO.18
NO.19
NO.20
STUDENT'S STATION NO.1
STUDENT'S STATION NO.10
STUDENT'S STATION NO.11
STUDENT'S STATION NO.20
INSTRUCTOR'S POSITION
STUDENTS' STATIONS'

Figure 4. Block diagram of SRGT.

Student Stations

The equipment at each student's station consists of a pair of headphones, an assembly of 70 pushbuttons, and an auxiliary manually operated key. Sixty-seven of the pushbuttons are numbered 1 to 67 inclusive; the remaining three are labeled "??," "Yes," and "No." (Some of the pushbuttons bear additional designations appropriate to the training material being used.) When one of the numbered nonlocking pushbuttons is depressed, that number appears in facsimile on the paper of one of the two monitor recorders at the instructor's position. The symbols ↑, X, and 0 respectively are reproduced when the pushbuttons marked "??," "Yes," and "No" are depressed. The facsimile reproduction is repeated approximately 50 times per minute as long as the pushbutton remains depressed. Responses from students' stations 1 to 10 inclusive appear on monitor recorder No. 1, whereas stations 11 to 20 inclusive are accommodated by monitor recorder No. 2. The instructor is provided with an identical set of pushbuttons, and his responses are reproduced simultaneously on both monitor recorders. When the manually operated auxiliary key at a student station (or at the instructor's position) is closed, a solid black line is reproduced on the paper of the monitor recorder in the column normally occupied by the second digit. In addition, the circuits are arranged to provide a rapid means of checking the responses of the students against the correct answers which the instructor places on the monitor recorder papers by employing his own pushbuttons for second-digit blanking. Suppose, for example, that the instructor depresses pushbutton 45 and at the same time closes the auxiliary keying circuit (by means of his auxiliary key or a toggle switch) at the instructor's position. The digit 4 followed by a black line will then appear in the columns of monitor recorder paper assigned to the instructor. If a student now depresses his pushbutton 45, the digit 4 followed by a black line will appear in the column assigned to that student's station; if the student depresses 35, a 3 followed by a black line will appear; and if he depresses any number not containing the digit 5, both digits will be reproduced in the normal manner.

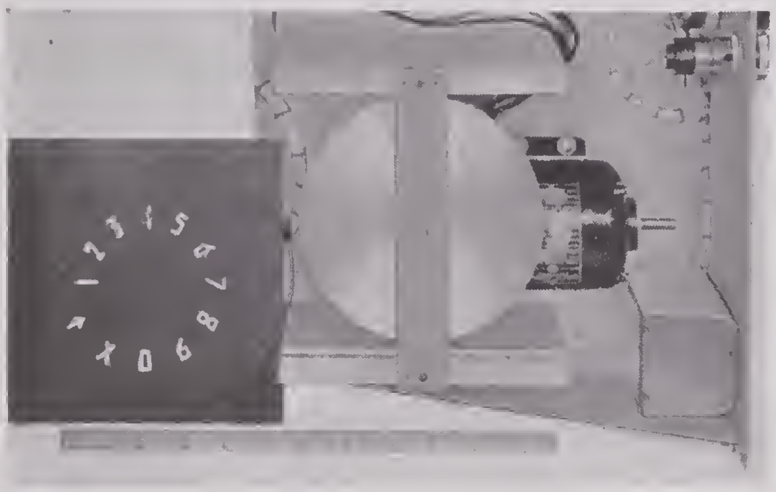


FIGURE 5. Scanning transmitter in SRGT.

FACSIMILE SYSTEM

The principles of operation of the facsimile system employed in the SRGT are described with the aid of figures showing, respectively, the scanning transmitter, the monitor recorder, and a simplified schematic of the electric circuits. The scanning transmitter, Figure 5, consists essentially of (1) a metal scanning disk driven at 50 rpm by a single-phase motor and (2) a block of insulating material, or template, containing metal inserts shaped like the numbers and symbols to be reproduced in facsimile. The scanning disk carries a spiral array of 21 spring-loaded pins which complete an electric circuit between the scanning disk and the metal inserts. The contact pins are so arranged that during one revolution of the scanning disk each metal insert is crossed by 11 pins, i.e., the electric circuit is opened and closed eleven times. The scanning of the inserts is done from the inside of the spiral outward (from the bottom

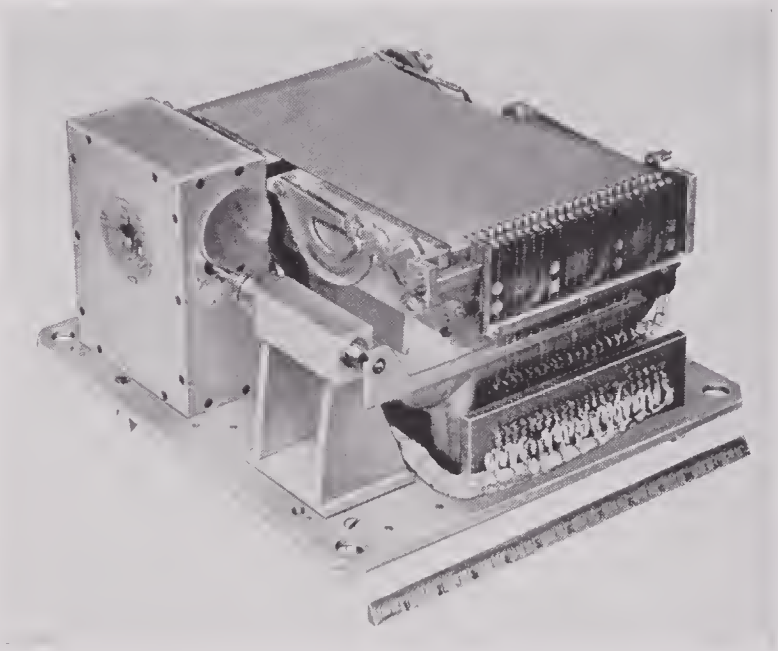


FIGURE 6. Monitor recorder for SRGT.

to the top of each number or symbol). Since the metal inserts have equal angular spacings and the contact pins move at a uniform rate, the length of time the electric circuit between a pin and an insert is complete (and hence the length of line reproduced on the monitor recorder paper) depends on the shape of the letter or symbol. The order of scanning is such that the corresponding one of the 11 lines for each number or symbol is reproduced on the monitor recorder paper at the same time.

Monitor Recorders

The monitor recorders (Figure 6) are tactical sound range recorders modified for this particular application. The recorder driving motor moves the paper 7½ in. per minute and, through a set of gears and a mechanical linkage, causes the stylus assembly to move horizontally back and forth across the paper twelve times while the scanning disk makes one revolution. The reciprocating movement of the stylus assembly and the rotation of the scanning disk are synchronized so that the styli start their horizontal traverse just before a pin on the scanning disk makes contact with a metal insert. When the electric circuit to a particular stylus is completed by depressing the appropriate student's or instructor's pushbutton, one trace will appear on the recorder paper for each traverse of the stylus, and a complete number or symbol will be reproduced during the time for 11 traversals. The time required for these traversals is $^{11}/_{12}$ of that required for one revolution of the scanning disk; during the remaining $^{1}/_{12}$ revolution, all pins ride on the insulating material of the template, and thus a space is provided between the successive facsimile reproductions on the monitor recorder paper.

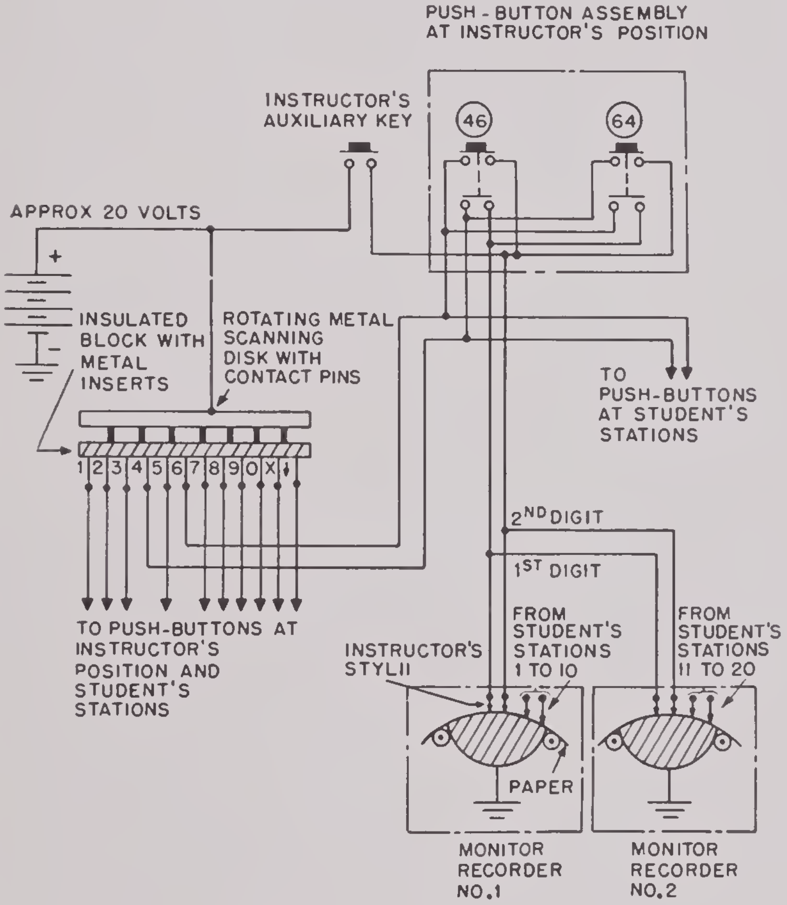

PUSH - BUTTON ASSEMBLY AT INSTRUCTOR'S POSITION
INSTRUCTOR'S AUXILIARY KEY
46
64
APPROX 20 VOLTS
+
-
INSULATED BLOCK WITH METAL INSERTS
ROTATING METAL SCANNING DISK WITH CONTACT PINS
TO PUSH-BUTTONS AT STUDENT'S STATIONS
1 2 3 4 5 6 7 8 9 0 X
2ND DIGIT
1ST DIGIT
TO PUSH-BUTTONS AT INSTRUCTOR'S POSITION AND STUDENT'S STATIONS
INSTRUCTOR'S STYLII
FROM STUDENT'S STATIONS 1 TO 10
FROM STUDENT'S STATIONS 11 TO 20
PAPER
MONITOR RECORDER NO.1
MONITOR RECORDER NO.2

Figure 7. Functional schematic of facsimile system of SRGT.

The arrangements for completing the electric circuits to the various styli by means of the pushbuttons is shown in Figure 7 (only the circuits associated with the instructor's pushbuttons 46 and 64 are given in detail). This schematic shows how the desired metal inserts are connected to the stylus associated with the first or second digit by means of the pushbuttons. The circuits from the students' stations are similar, with the exception that only one pair of styli are associated with each station. When the instructor's auxiliary key is closed, the stylus associated with the second digit is energized continually and a solid line appears on the monitor recorder paper. If the instructor depresses simultaneously his auxiliary key and one of his numbered pushbuttons, the second digit of that number will be blacked out wherever it would normally appear (depending upon which pushbuttons are depressed at the students' stations).

A complete description of power and amplifier circuits and interconnections together with operating and maintenance instructions may be found in the microfilmed reports on the SRGT listed in the bibliography.

Phonograph Recordings

The phonograph recordings prepared for use with the SRGT provide drills in order of increasing difficulty, and test turn-count estimation, faint contact detection, target identification, and other auditory discriminations.

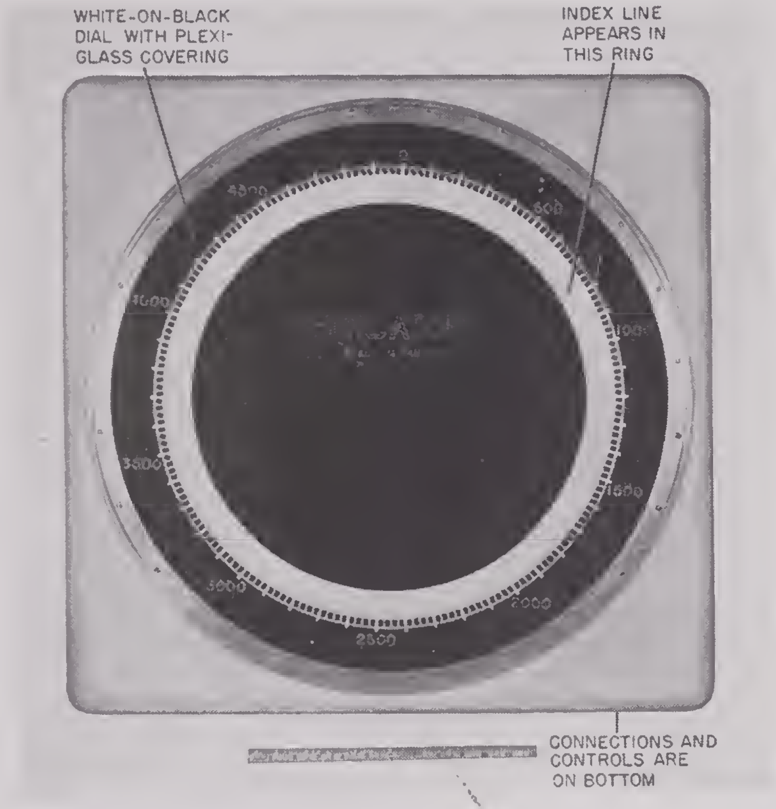

WHITE-ON-BLACK DIAL WITH PLEXI-GLASS COVERING
INDEX LINE APPEARS IN THIS RING
0
500
1000
1500
2000
2500
3000
3500
4000
4500
CONNECTIONS AND CONTROLS ARE ON BOTTOM

FIGURE 8. Range indicator trainer, front panel.

Range Indicator Trainer

The range indicator trainer [RIT], developed by UCDWR, is an enlarged range indicator of the type found on WCA submarine sonar equipment. It is used with the sound recognition group trainer [SRGT] to train students in single-ping range reading and in estimating ranges from secondary echoes, as well as in estimating the echo-ranging interval of an enemy ship. It has a round dial, calibrated from 0 to 5,000 yd, and a short index line of light that moves clockwise over a path adjacent to the dial scale. For single-ping ranging exercises, the RIT can be automatically synchronized with the SRGT disk-recorded selections, so that the index line lights up and begins to rotate from 0 at the time of each ping transmission. After one revolution, the index line disappears, and the mechanism of the RIT stops until the cycle is begun again at the next ping transmission.

The front panel of the range indicator trainer, shown in Figure 8, looks like an enlarged version of Type WCA range indicator.

The primary purpose of the RIT is to permit realistic training in single-ping range reading. At the same time, synchronized operation permits the instructor to focus the attention of his class on a particular sound. He points to the dial at the range of the sound in question, and the students concentrate on what they hear as the index line passes the indicated range.

By setting the RIT to run continuously and independently of the recorded selections, further uses can be made of the device. The students can use the indicator as a timer for turn counts by converting the indicated yards to seconds (800 yd equal 1 sec). Besides being convenient in the classroom, this timing method is important because it can be used aboard ship. The techniques of ranging by secondary echoes and of determining echo-ranging interval can also be practiced when the RIT is set to operate continuously. These techniques are briefly described as follows: Under certain sound conditions, secondary echoes from enemy pinging are prominent enough to allow the sonarman to estimate range by observing the difference in indicator readings between the time of a ping and that of a ping echo from the enemy ship. Whenever enemy pinging is heard, the interval of echo ranging can be determined by observing the difference in indicator readings between successive pings.

14.2 GENERAL DESCRIPTION

Figure 9 shows the RIT with the dial and the front part of the cabinet removed. The mechanical-electrical assembly is fastened to the center of the rear panel. The cable running from the assembly to the bottom of the cabinet connects (from left to right) to the 115-volt a-c plug, the power switch, the fuse, the pilot light, the run-keying switch, and the connector to the pulse line from the SRGT. With power and pulse line connections made, the device is put into operation by snapping the power switch to on and by setting the other switch to run if continuous operation is desired, or to keying if the indicator is to be synchronized with the SRGT recorded selections.

If the RIT is placed in a long classroom, it may be necessary to substitute larger dial numbers than those marked on the dial, using pasteovers on the Plexiglas dial cover. This will be especially necessary if there is any troublesome glare. The white ring immediately inside the dial scale is translucent, so that the index line, which is projected from an optical system behind the dial, shows through.

Mechanical Assembly. Figure 10 is a close-up of the mechanical-electrical assembly of the range indicator trainer. Mounted on the frame is the lens-arm assembly that carries the index-line optical system. Two sets of ball bearings hold the lens-arm assembly shaft perpendicular to the front of the frame and 2⅛ in. down from the top. Rigidly clamped to the shaft is the lens arm, which carries at its extremity a 6-volt lamp, a cylindrical lens, and a light shield. The latter three elements are arranged to focus a sharp index line on the back of the dial. A 120-tooth driven gear, also clamped rigidly to the shaft, engages a 19-tooth pinion of a 60-rpm Telechron motor, which is mounted at the top of the frame. Current for the 6-volt lamp enters the lens-arm assembly through a contact button at the inside end of the shaft. An insulated wire, which passes through the hollow shaft, connects the contact button to the lamp. The current returns through the metal parts of the lens-arm assembly and passes to the frame through two carbon brushes in contact with the side of the driven gear.

A cam is fixed to the rest of the lens-arm assembly by a ⅛-in. rod, which is perpendicular to the shaft and is displaced by 180 degrees from the lens arm. The cam serves two purposes: it operates a microswitch when the index line reaches 0, and it counterbalances the lens arm.

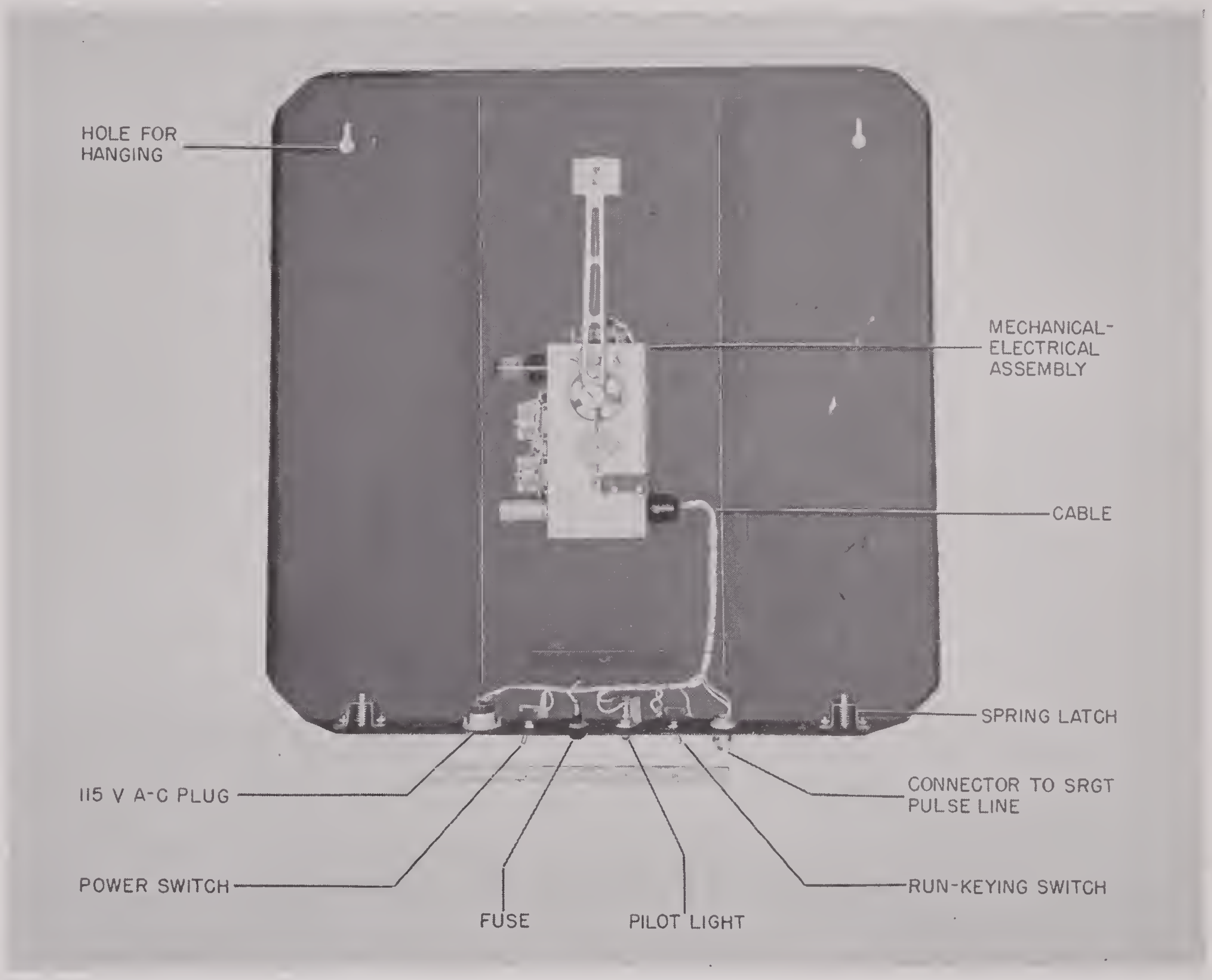


FIGURE 9. Range indicator trainer with front panel removed.

On the left side of the frame are mounted (from top to bottom) a 6x5 tube, two Leach Type 1127 relays, and a 10-10 μfd condenser. A single-pole, double-throw microswitch is mounted on the front of the frame about two inches from the bottom. An octal socket for connections to external circuits is near the bottom of the right side of the frame. A 115/6.3-volt transformer is mounted inside the frame on the left side.

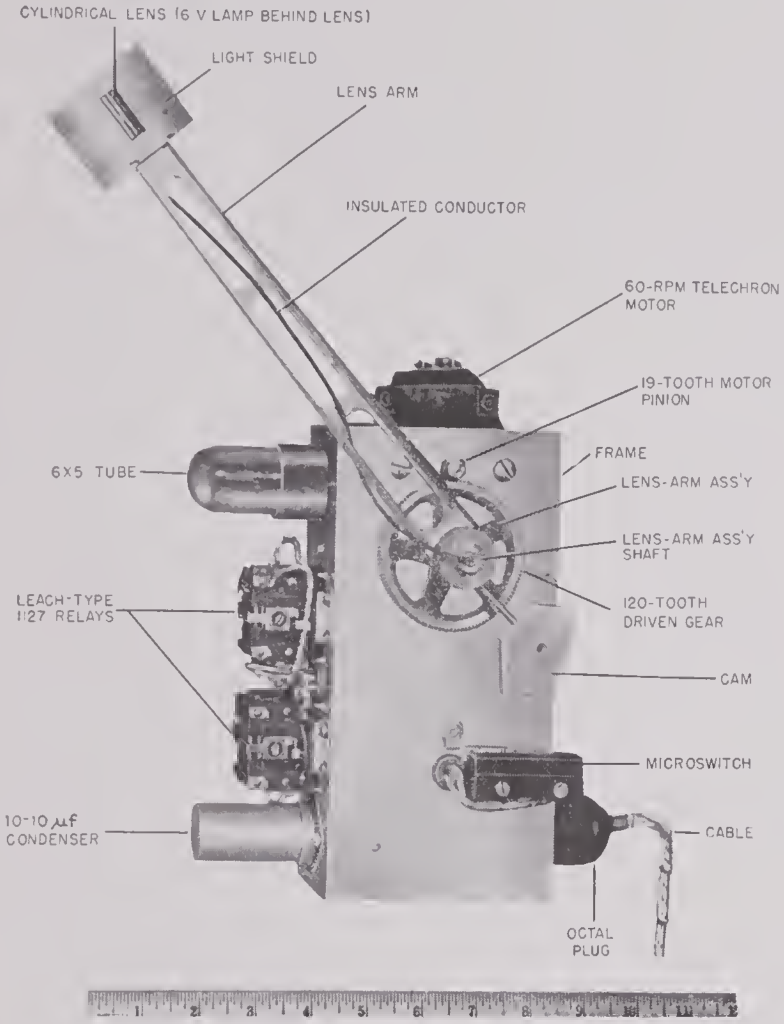

CYLINDRICAL LENS (6 V LAMP BEHIND LENS)
LIGHT SHIELD
LENS ARM
INSULATED CONDUCTOR
60-RPM TELECHRON MOTOR
19-TOOTH MOTOR PINION
6X5 TUBE
FRAME
LENS-ARM ASS'Y
LENS-ARM ASS'Y SHAFT
LEACH-TYPE 1127 RELAYS
120-TOOTH DRIVEN GEAR
CAM
MICROSWITCH
10-10 μf CONDENSER
CABLE
OCTAL PLUG

FIGURE 10. Mechanical-electrical assembly of the range indicator trainer.

Electric Circuit. Figure 11 shows the electric circuit for the range indicator trainer. One side of the 115-volt power line runs directly from J-703 to terminal 3 of P-701. The other side of the power line first goes through fuse F-701 and power switch S-701 and then connects to terminal 4 of P-701. Terminals 3 and 4 of J-701 supply 115-volt alternating current to (1) the primary of transformer T-701 and (2) the charging circuit of condenser C-702, which includes tube V-701 and resistor R-701. The secondary of transformer T-701 supplies 6.3 volt alternating current to (1) pilot lamp I-702 through the J-701 to P-701 terminals 7 and 8, (2) index-line lamp I-701 through the sliding contacts, the contact button, and the contacts of relay K-701, and (3) the heater of tube V-701.

When switch S-702 is set at run, terminals 3 and 5 of J-701 supply 115-volt alternating current to (1) motor B-701 and (2) relay K-701 through condenser C-701. These connections cause the index line to rotate continuously and the index-line lamp (I-701) to remain on.

When switch S-702 is set at keying, the voltage on terminal 5 (the motor and index-line lamp control terminal) of J-701 depends upon the connections to terminal 6 of J-701. Terminal 6 connects to the contacts of the pulse relay K-702 and to the microswitch. For ease of discussion, the normally closed contacts of the relay and the microswitch have been labeled "A," and the normally open contacts have been labeled "B." Table 1 analyzes the switching con-

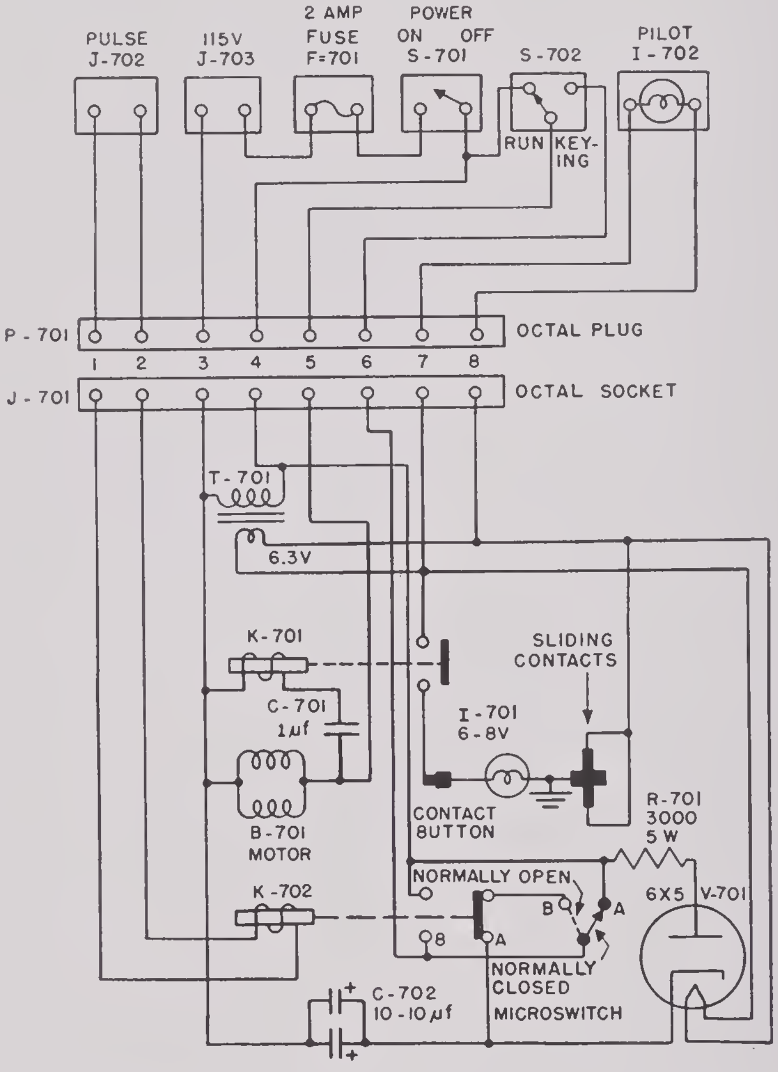

PULSE J-702
115V J-703
2 AMP FUSE F=701
POWER ON OFF S-701
S-702
RUN
KEY-ING
PILOT I-702
P-701
OCTAL PLUG
1 2 3 4 5 6 7 8
J-701
OCTAL SOCKET
T-701
6.3V
K-701
SLIDING CONTACTS
C-701 1μf
I-701 6-8V
B-701 MOTOR
CONTACT BUTTON
R-701 3000 5W
NORMALLY OPEN
B
A
6X5 V-701
K-702
8
A
NORMALLY CLOSED MICROSWITCH
C-702 10-10μf

FIGURE 11. Electrical schematic of the range indicator trainer.

ditions in the order of their occurrence. The function of C-701 is to keep the d-c braking current from going through the coil of K-701. During the periods when the motor is at rest and C-702 is charging, the resistor R-701 limits the pulsating direct current through V-701.

TABLE 1

Initial status of index line	Closed contacts K-702	microswitch	Remarks
At rest at 0. I-701 extinguished.	A	B	No voltage on coil of K-702. Cam holds microswitch at B. Low value of direct current is fed to motor through R-701 and V-701. No change in status.
At rest at 0. I-701 extinguished.	B	B	Voltage pulse on coil of K-702. Cam holds microswitch at B. 115-volt alternating current through K-702 B contacts, starts motor, lights I-701. C-702 charges.
In motion near 0. I-701 lit.	B	A	Voltage pulse continues on coil of K-702. Cam release microswitch to A. 115-volt alternating current through both K-702 B contacts and microswitch. A contact runs motor, lights I-701. C-702 continues to charge.
In motion around dial. I-701 lit.	A	A	Voltage pulse has ended, causing A contacts to close, B contacts to open on K-702. 115-volt alternating current through microswitch. A contact runs motor, lights I-701. C-702 continues to charge.
Approaching 0. I-701 lit.	A	B	No voltage on coil of K-702. Cam closes microswitch B contact. 115-volt alternating current cut off from motor and I-701 control relay (K-701). Charge of C-702 surges through K-702 and microswitch contacts and through motor to give braking action. Motor stops. I-701 is extinguished. Cycle is completed.

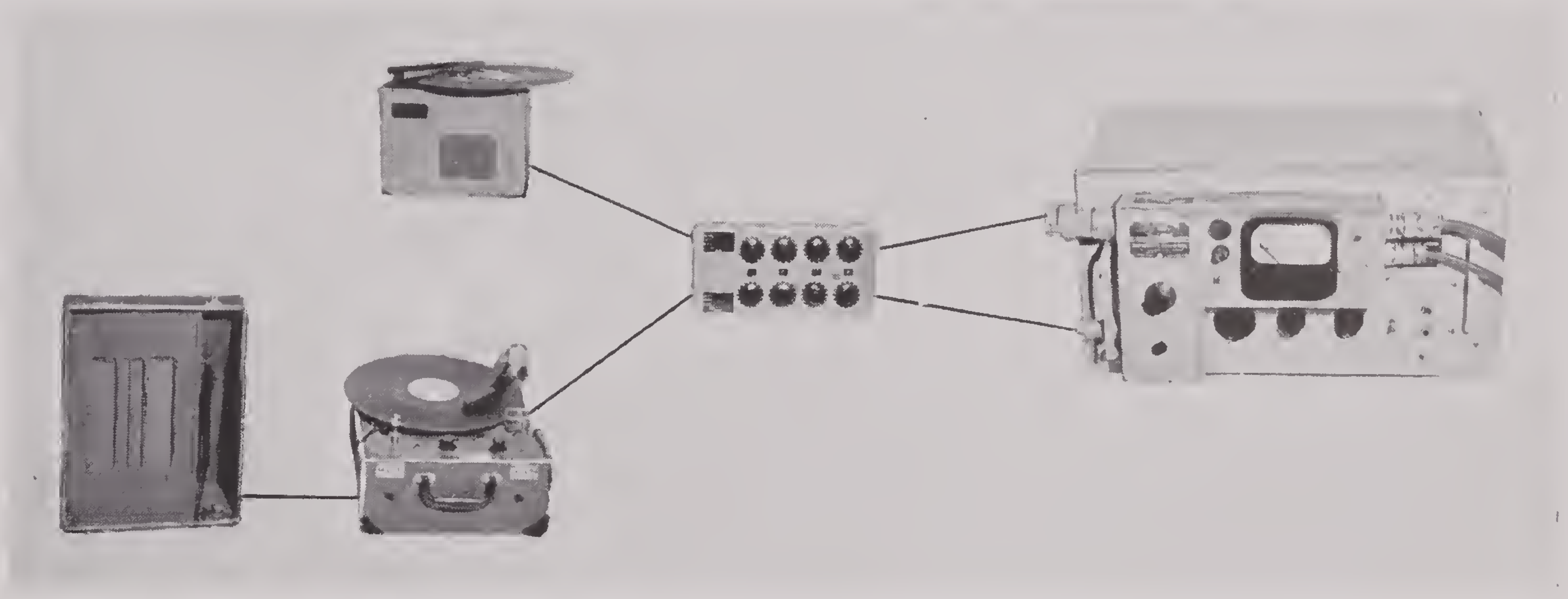


FIGURE 12. Noise level monitor trainer.

Noise Level Monitor Trainer

The noise level monitor [NLM] trainer, developed by CUDWR-NLL, introduces into a standard noise level monitor sea-recorded background and auxiliary noise to familiarize the student with various types of NLM readings and their correct interpretation. An NLM attached to a JP amplifier, a control unit, a loudspeaker, and two playbacks are used. The noise recordings utilized in this equipment were obtained through submarine-mounted NLM hydrophones.

The noise-level monitor trainer equipment is shown in Figure 12. It operates on 110-volt d-c power supply. The JP amplifier with NLM chassis mounted, is a duplicate of a shipboard installation, except for a few minor modifications in the amplifier to adapt it for use with the trainer. Chief among these is the disconnection of the positive d-c lead from the magnetizing switch to protect the trainer control unit from accidental discharge of the magnetizing current.

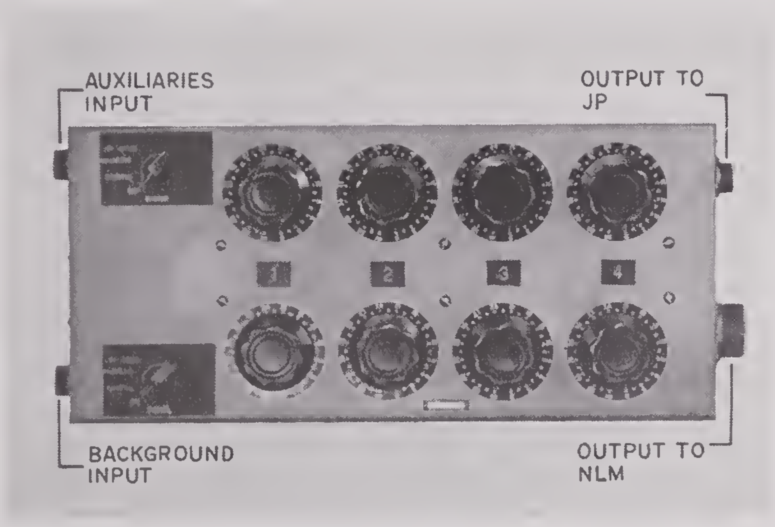

AUXILIARIES INPUT
OUTPUT TO JP
1
2
3
4
BACKGROUND INPUT
OUTPUT TO NLM

FIGURE 13. NLM trainer control unit.

The control unit, shown in Figure 13, consists essentially of two sets of variable attenuators, one set for the background channel, the other set for the auxiliaries channel. Recorded background noise is fed into the background channel, and auxiliary noise from various submarine auxiliaries in order of increasing difficulty into the auxiliaries channel. The combined output of any pair of attenuators (for example, No. 1 background and No. 1 auxiliaries) represents the output of one NLM hydrophone. There is a realistic addition of levels. Thus if an auxiliary measuring 23 db by itself is mixed with a background measuring 20 db, the NLM reading will be about 25 db. Figure 14 is a schematic showing the electric circuits.

The output of the control unit passes through a shielded cable to the NLM chassis mounted on

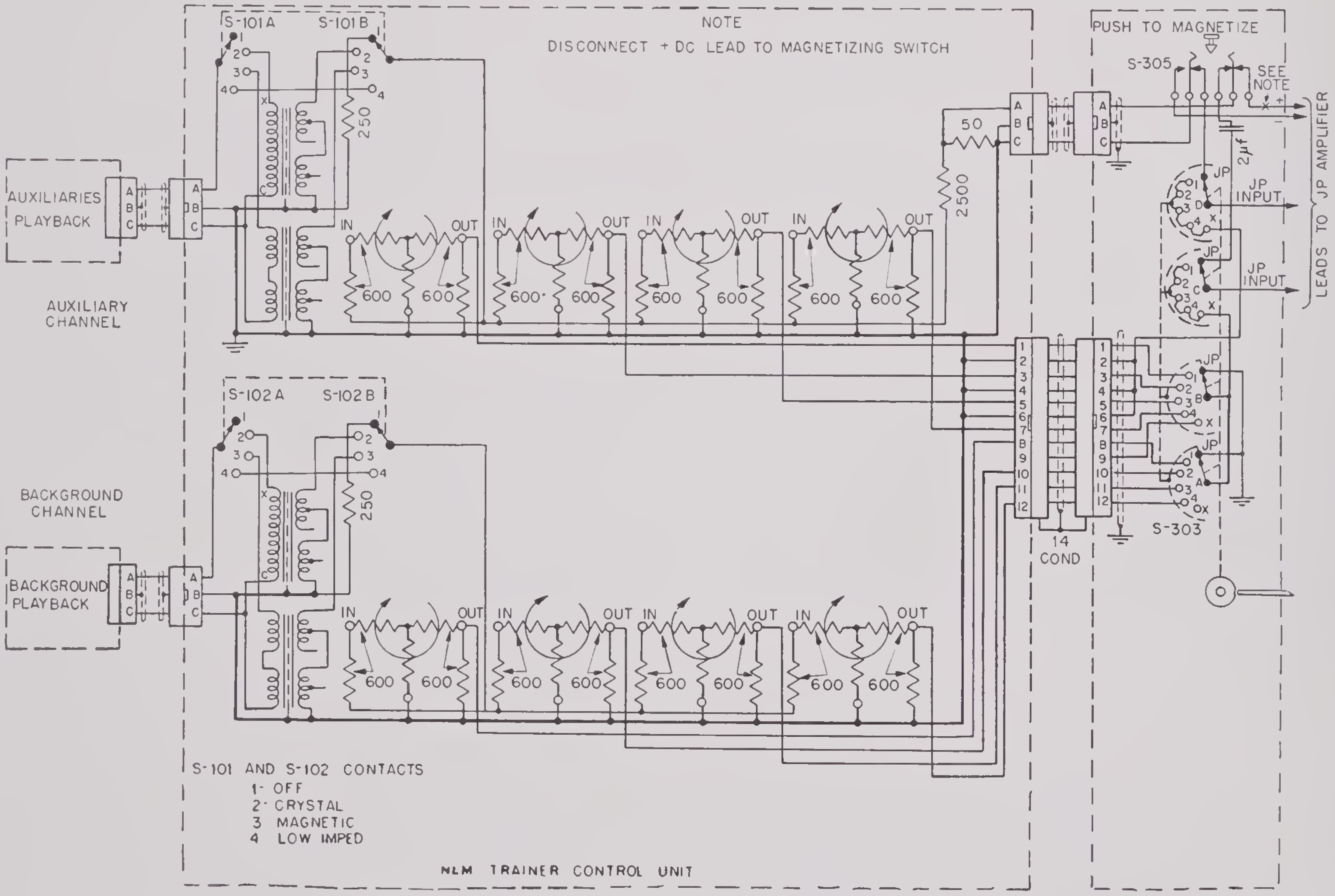

S-101A
S-101B
NOTE
DISCONNECT +DC LEAD TO MAGNETIZING SWITCH
PUSH TO MAGNETIZE
S-305
SEE NOTE
250
50
2500
2μf
AUXILIARIES PLAYBACK
AUXILIARY CHANNEL
IN
OUT
600
JP INPUT
JP INPUT
LEADS TO JP AMPLIFIER
S-102A
S-102B
BACKGROUND CHANNEL
BACKGROUND PLAYBACK
14 COND
S-303
S-101 AND S-102 CONTACTS
1- OFF
2- CRYSTAL
3 MAGNETIC
4 LOW IMPED
NLM TRAINER CONTROL UNIT

FIGURE 14. Electrical schematic for the NLM trainer.

Table 2. NLM trainer control-unit settings.

Form	Record number	Auxiliaries measured	Control-unit settings								Desired NLM readings*			
			background attenuators				auxiliaries attenuators							
			1	2	3	4	1	2	3	4	1	2	3	4
Form 1. NLM calibration measurements (individual auxiliaries)	4	Water noise only background	–	–	–	–					7	11	9	6
	1	Forward gyro set reg. power					–	–	–	–	25	16	10	8
	1	QB sound training motor generator					–	–	–	–	36	14	11	8
	1	No. 2 air conditioning					–	–	–	–	10	19	11	7
	2	Refrigeration plant					–	–	–	–	9	16	11	7
	2	Hull ventilation blower supply					–	–	–	–	8	11	19	6
	2	Aft. gyro setting regulator, power					–	–	–	–	12	14	10	27
Form 2. Calibration (overall)	3	Rigged for silent running, 40 rpm	–	–	–	–					37	25	26	20
	3	Normal submerged operation, 40 rpm	–	–	–	–					36	37	32	34
Form 3. Daily check (overall)	3	Rigged for silent running, 40 rpm	–	–	–	–					37	27	27	21
	3	Normal submerged operation, 40 rpm	–	–	–	–					37	38	33	34
Form 1. NLM patrol measurements (suspected auxiliaries)	3	Minimum evasive machinery, 40 rpm	–	–	–	–					15	20	22	20
	1	No. 2 air conditioning plant					–	–	–	–	16	23	22	20
	2	Refrigeration plant					–	–	–	–	16	37	22	20

* These are plausible relative levels. The actual readings may vary 2 or 3 db either way. This is probably caused by variations in the amplifier, pickup, phonograph records, or power supply. It means that the instructor cannot tell from the attenuator settings *exactly* what the meter readings will be. He must observe the meter while the students get the readings.

a JP amplifier. From here the signal is fed through the amplifier of a playback to a loudspeaker, so the students can read the meter and hear the sounds as well. The controls of the NLM are used just as in normal operation.

A separate cable runs from the control unit to the JP receptacle, providing a nonvariable noise level through the auxiliaries channel, when the NLM selector switch is turned to the JP position.

The two small switches at the left of the panel provide means for matching the input impedances of the two channels to the impedances of the pickups on the two playbacks. The off position turns off the signal in that particular channel, even if a record is playing. The magnetic position, used with magnetic pickup, provides an impedance of 5,000 to 8,000. The crystal position, used with crystal pickup, provides an impedance of 100,000 ohms.

Any type of crystal or magnetic pickups may be used, but since individual playbacks vary considerably, it is necessary to calibrate the control unit of each trainer before putting it into operation in the classroom, so that the instructor will know what attenuator settings to use in the drill. Table 2 shows a complete NLM drill,[1] including the NLM readings desired in each case, and blanks for the control unit settings necessary to get those particular readings.

The recordings used with the trainer are 16-in. disks, playing at 33⅓ rpm, of sounds received through four NLM hydrophones mounted on a submarine's pressure hull. The auxiliary set simulates submarine auxiliaries under different conditions, such as the submarine lying on the bottom (background noise only), minimum evasive, rigged for silent running, and normal submerged. In the more complex drills, high noise levels are reproduced, and the procedure for testing individual auxiliaries to locate the noisy one requiring repair can be illustrated.

Torpedo Detection Modification Trainer

The torpedo detection modification [TDM] trainer, is an adaptation of the QFL range recorder teacher. Five TDM bearing recorders have been substituted for the range recorders. This adaptation was given the Navy designation QFM. The QFL type of amplifier and control unit, playback, and loudspeaker are used in the QFM, but the recordings are of torpedo sounds instead of echoes and reverberation. These simulated torpedo sounds produce characteristic traces on the bearing recorders, and at the same time are heard through the loudspeaker. TDM was developed by CUDWR-NLL.

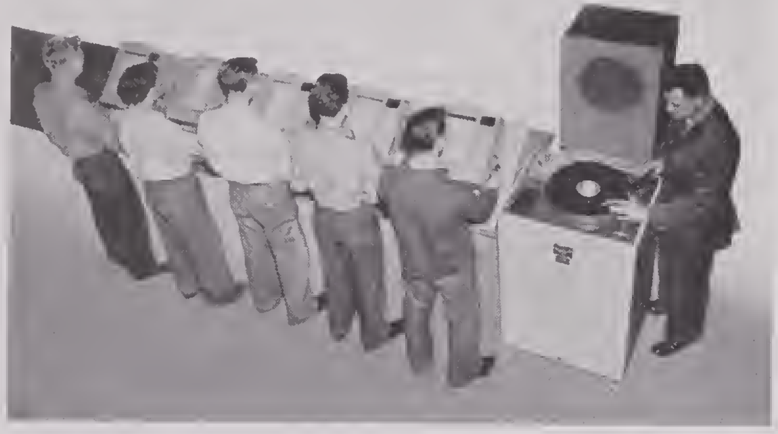


FIGURE 15. The TDM trainer.

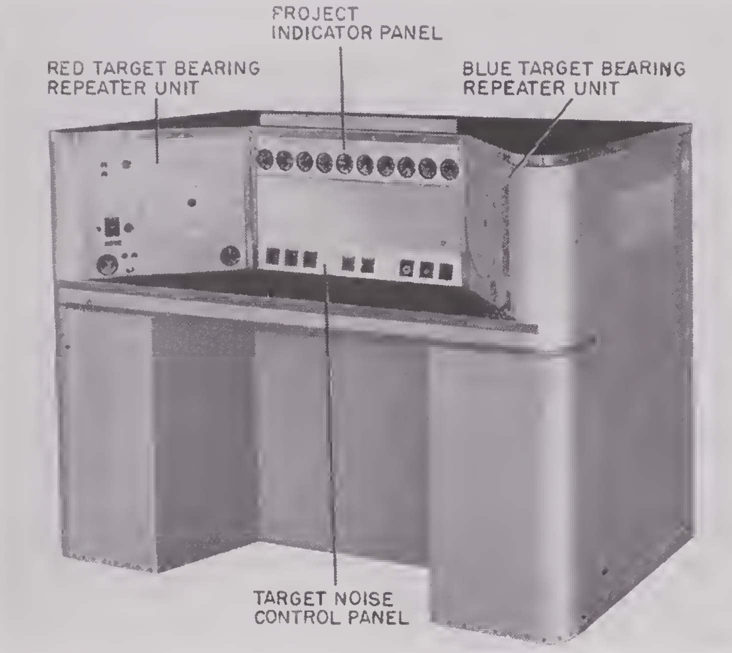

PROJECT INDICATOR PANEL
RED TARGET BEARING REPEATER UNIT
BLUE TARGET BEARING REPEATER UNIT
TARGET NOISE CONTROL PANEL

FIGURE 16. Group listening teacher, instructor's position. Note: "Project Indicator Panel" should read "Projector Indicator Panel."

Group Listening Teacher

The group listening teacher [GLT], developed by UCDWR, is a device which realistically simulates the principal sounds heard by submarine sonar operators during important tactical situations, coordinates these sounds into three problems, each involving two targets and own-ship's interference, and then applies them to five standard WCA-type sonar equipments enclosed in separate sound-treated booths. Interchangeable motor-driven cams control the variables of each problem. Ten operators receive training simultaneously (JK and QB operators at each equipment), and one instructor at a central console is able to monitor the performance of all ten operators continuously. It is possible also to incorporate eight JP and four WEB equipments into the trainer.

The group listening teacher was an outgrowth of the *advanced listening teacher* [ALT], which provided training for only one submarine sonar operator at a time. It is essentially an extension of the principles of the ALT automatic problem generator to affect ten or more student operator stations simultaneously. The variables of each problem are controlled by a set of motor-driven cams, and the shifting from one problem to another is accomplished by changing to a different set of cams. The two targets involved in each of the three problems are designated "red" and "blue." Own-ship's noise as well as a variety of water conditions and propeller sounds may be simulated, and pinging by one of the enemy targets may be injected into the problem by the instructor at will. Any one of the QB operators, according to the instructor's choice, may obtain single-ping ranges on one of the targets. An intercommunicating system is used for two-way conversation between the instructor and the students, and for monitoring the students, either individually or collectively.

14.3 GENERAL DESCRIPTION

The description which follows deals only with the WCA portion of the group listening teacher, Model CXKG (formerly designated Model I, WCA). Each of the five WCA equipments in this portion of the trainer is installed in a separate soundproof booth, and the student can manipulate the controls in exactly the same way as under actual operating conditions. Problem information from the instructor's control cabinet is transferred to each WCA stack through a search unit mounted above the booth.

Switches for controlling the training problem and the instruments for monitoring the students' performance are mounted on the front panels of the control cabinet, as shown in Figure 16. These controls and their principal functions are described below.

Red Target-Bearing Repeater Unit

A problem selector switch is used for selecting one of the three problems to be used (see Figure 17). A three-position toggle switch controls the operation of the motor which drives the problem generating cams. When this switch is in the right-hand position, the problem proceeds at a rate normal to the simulated tactical situation. When this switch is in the left-hand position, the camshaft is made to turn in the reverse direction at approximately ten times normal speed, thus facilitating the repetition of any part of a problem or the starting of a problem at any point. The cams are stopped when this switch is in the center position, thus holding the target range and bearing fixed while all simulated sounds are produced in the regular manner. An indicator, calibrated in ½-minute steps from 0 to 20 minutes, shows the time elapsed since the start of the problem (a measure of the angular position of the camshaft). A standard bearing repeater arrangement indicates the true and relative bearing of the simulated red target. An indicator, calibrated in 100-yd steps from 0 to 5,000 yd, shows the approximate range of the red target.

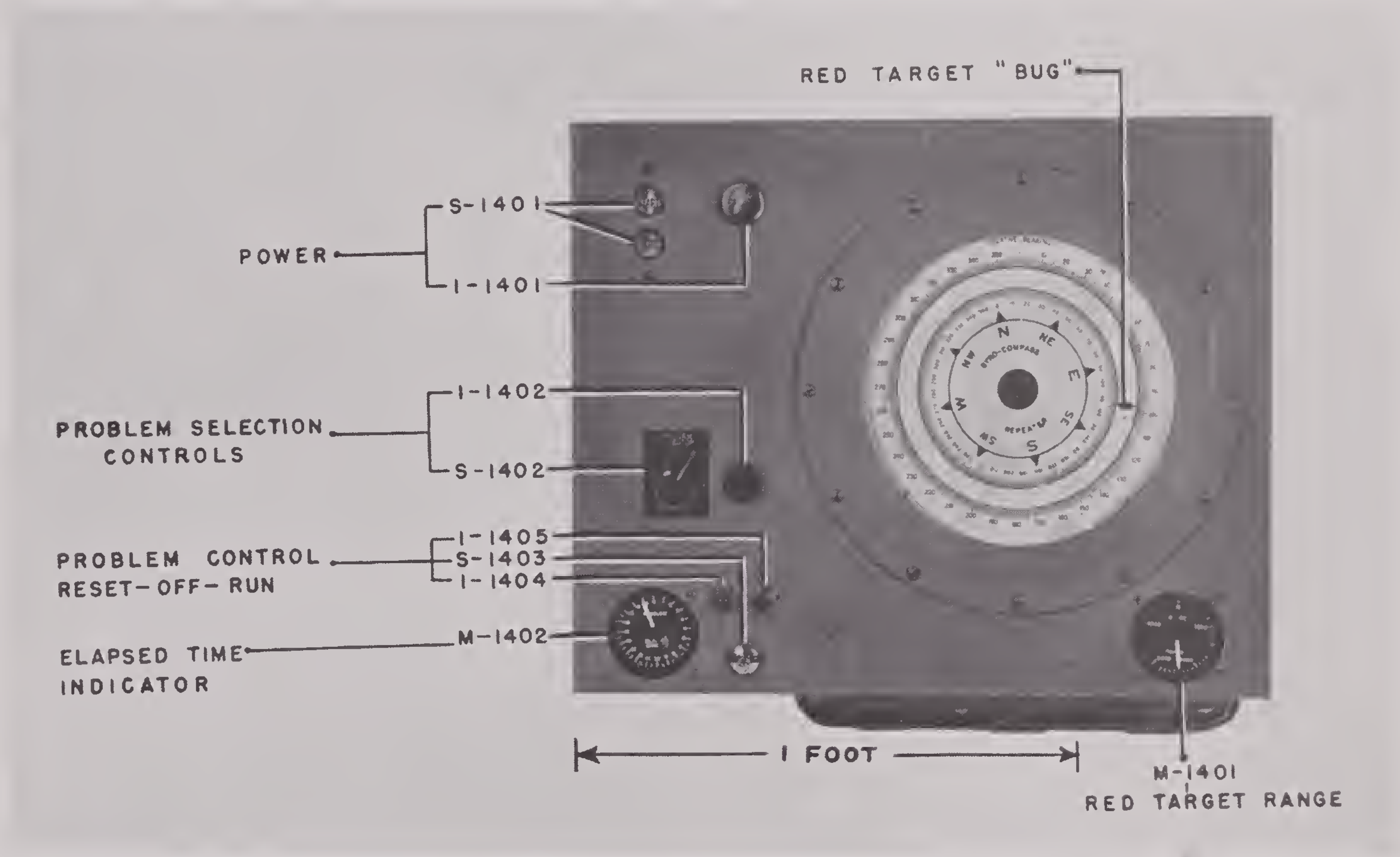


Figure 17. Red target bearing repeater unit.

Blue Target-Bearing Repeater Unit

A standard bearing repeater arrangement indicates the true and relative bearing of the simulated blue target (Figure 18). An indicator, calibrated in 100-yd steps from 0 to 5,000 yd, shows the approximate range of the blue target. A three-position key switch and a set of pushbutton switches control an intercommunicating system between the instructor and the students' booths. By depressing the proper pushbutton, the instructor may hold a two-way conversation with any one of the ten students or with all simultaneously. When the key switch is in the "listen receivers" position, the instructor hears the same sounds that the student hears and also hears the students' oral reports.

Projector Indicator Panel

This panel contains ten indicators calibrated in 15-degree steps from 0 to 360 degrees, which show the relative bearing of the simulated JK and QB projectors associated with the WCA equipments (Figure 16).

Target Noise Control Panel (Figure 16)

A single-ping QB switch is used to determine to which one of the five QB operators the simulated single-ping reverberation and echo are available. An enemy ping frequency switch enables selection of either 17 or 27 kc as the enemy echo-ranging frequency. An enemy ping interval control enables setting the enemy echo-ranging keying interval at any value between 500 and 3,500 yd. Two screw selector switches, one for the red target and one for the blue target, each permit the independent choice of any of five simulated screw sounds. A torpedo explosion switch is used to initiate the simulated explosion. A torpedo problem toggle switch in the on position allows simulated torpedo sounds to reach the students. A water-conditions switch determines the intensity of the simulated background noise applied to the receivers in the WCA equipments. Three noise levels are available, corresponding to good, medium, and bad water conditions.

A functional block diagram of the problem-generating features of the Model CXKG is given in Figure 19. Mechanical linkages are shown as dashed lines, electrical as solid. The variables of a problem (speed, range, bearing, and doppler) are controlled by a set of ten cams, shown at the bottom of the figure, driven by constant-speed motor B-1201. This motor also drives a position transmitter R-1210 associated with an indicator M-1402 (on the panel of the red target-bearing repeater unit) which provides a measure of the angular position of the cams, i.e., of the portion of the problem being generated. This indicator enables the instructor conveniently to set the cams to any predetermined position called for by the instructional program. Similar position transmitters R-1203 and R-1209, driven by the blue and red target range cams, provide indications of the approximate range of each target to the instructor's position.

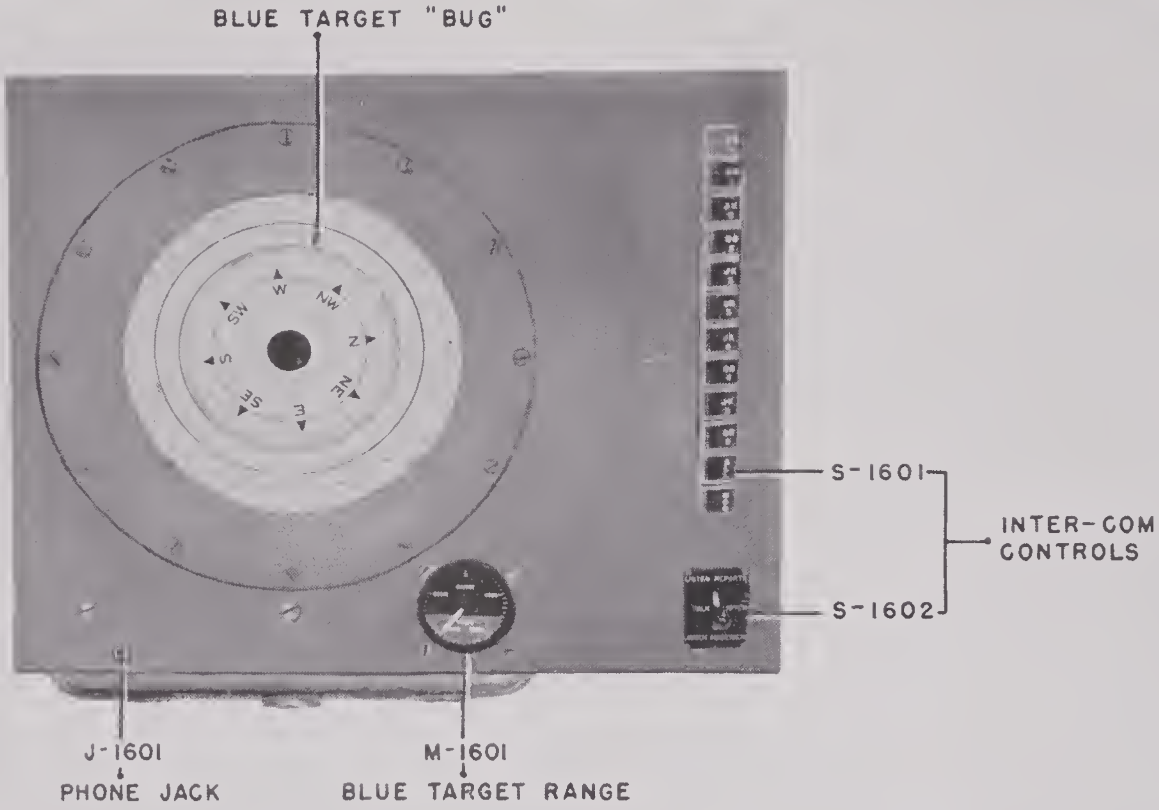


Figure 18. Blue target bearing repeater unit.

Screw Sounds. Own-screw sounds are generated by means of a glass disk rotating between a light source and a photoelectric cell PE-1202. Opaque segments of suitable size, spacing, and density have been deposited on this disk, so that the intensity of the light beam, and hence the output of the photoelectric cell, is varied in accordance with the desired screw sounds. The revolutions per minute of the simulated screws depend on the speed of rotation of the glass disk. This disk is driven by the output shaft of a conventional type of mechanical speed changer. The constant-speed disk of the speed changer is driven by motor B-1204, while the output roller is moved across the face of the constant-speed disk by the own-speed cam. Thus the speed of rotation of the glass disk, and hence the revolutions per minute of the simulated own screws, is made to vary with own speed as the problem progresses. The volume level, or intensity, of the simulated screw sounds depends on the intensity of the light source. Power for the source is obtained from transformer T-504 through resistor R-1204. The latter is also varied by the own-speed cam, and provides the desired variation of intensity of own-screw sounds with speed.

Screw sounds for the red and blue targets are generated in the same manner as described in the previous paragraph. In order that a variety of targets may be available for training purposes, each of the glass disks in the target screw-sounds generators has five sets of opaque segments, each set simulating a different type of target and having a separate light source. The choice of simulated screw sounds to be used is made by means of the screw selector red target and screw selector blue target switches S-1503 and S-1504 on the target noise control panel at the instructor's position. These switches have off positions so that a problem involving only one target can be run when desired. Resistors R-1201 and R-1206, driven respectively by the blue target and red target speed cams, provide for the variation of intensity of target screw sounds with target speed as the problem progresses (intensity proportional to speed up to 12 knots; constant thereafter). The glass disks are driven through speed changers as previously described so that the revolutions per minute of the simulated screws vary with target speed.

Random Noise. The output of each photoelectric cell, PE-1201, PE-1202, and PE-1203, is amplified by a separate screw-sounds amplifier and then fed to a mixer tube where it is combined with random noise. The spectrum of this random noise, generated by a gas tube, extends to at least 35 kc, hence the output of each mixer is a wide-band supersonic signal of random noise modulated with the screw characteristics as determined by the interrupted light beam in the screw-sounds generator. The own-screw-sounds mixer output is fed directly to the search units, whereas the red target and blue target mixer outputs are fed to the search units through resistors R-1207 and R-1202 respectively. These resistors are controlled by the red target and blue target range cams and cause the intensity of the target signals to vary with range.

Part of the output of the random-noise generator is fed through water-conditions switch S-1506 on the panel of the target noise control panel and resistor R-1205 to the inputs of both the JK and QB receivers in each WCA equipment to simulate nondirectional background and water noise. Switch S-1506 has three positions, these representing bad, medium, and good water conditions. Resistor R-1205 is driven by the own-speed cam and causes the intensity of the water noise to vary with own speed.

Bearing Information. The own-bearing cam drives synchro generator G-1201, which then supplies true-bearing information to gyro-compass repeaters in the red target-bearing repeater unit and the blue target-bearing repeater unit at the instructor's position, and to the QB and JK gyro-compass repeaters in each of the five WCA equipments. The relative bearing of each target is obtained from the output of a differential, the inputs being from the own-bearing cam and one of the target-bearing cams. These differentials drive synchro generators G-1202 and G-1203, which supply, respectively, blue target and red target relative bearing information to the five search units.

All information, both own and target, that is a function of the projector bearing is supplied to each WCA equipment through its own

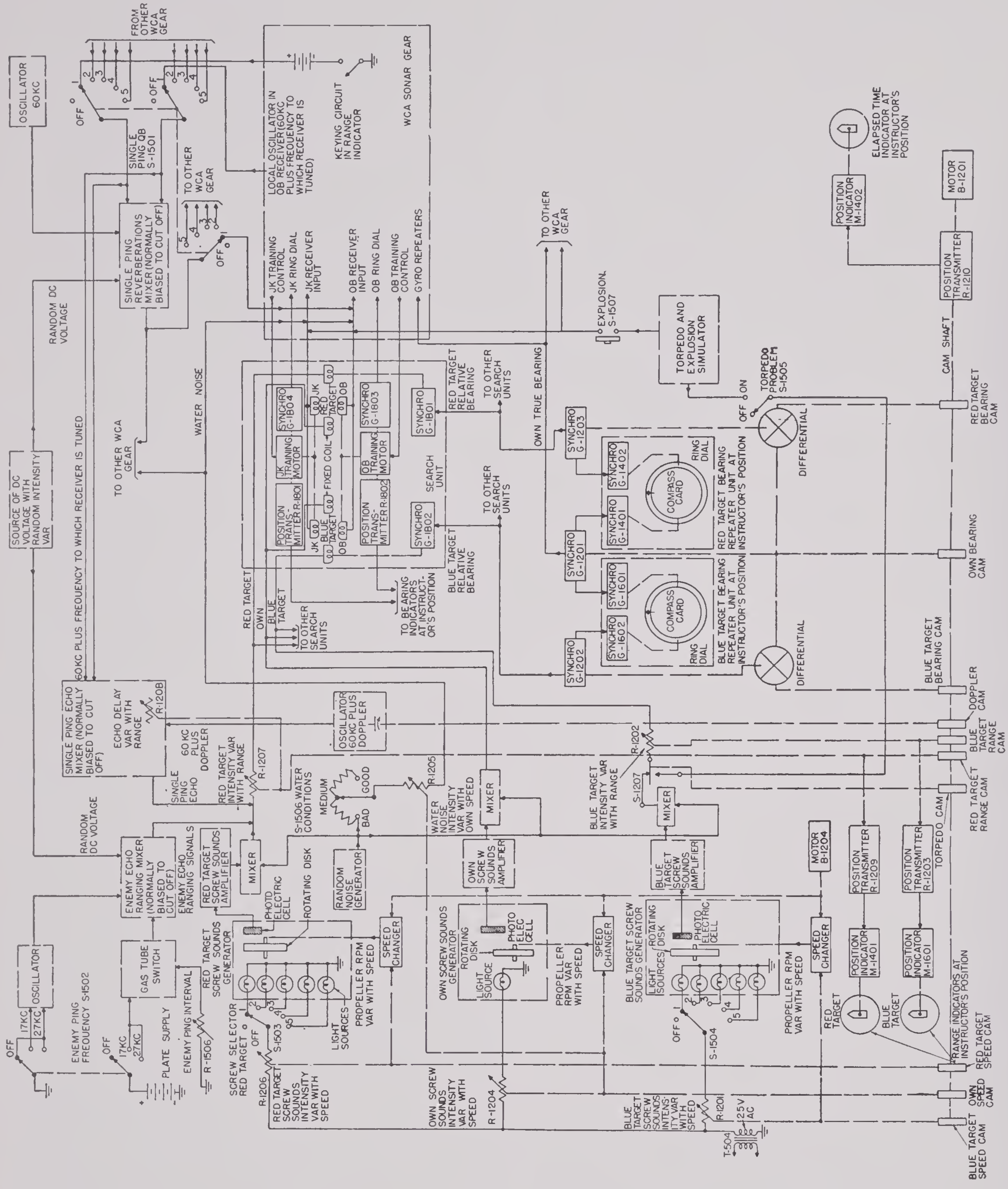

OSCILLATOR 60 KC
FROM OTHER WCA GEAR
SINGLE PING QB S-1501
OFF
TO OTHER WCA GEAR
SINGLE PING REVERBERATIONS MIXER (NORMALLY BIASED TO CUT OFF)
RANDOM DC VOLTAGE
LOCAL OSCILLATOR IN OB RECEIVER (60KC PLUS FREQUENCY TO WHICH RECEIVER IS TUNED)
KEYING CIRCUIT IN RANGE INDICATOR
WCA SONAR GEAR
JK TRAINING CONTROL
JK RING DIAL
JK RECEIVER INPUT
OB RECEIVER INPUT
OB RING DIAL
OB TRAINING CONTROL
GYRO REPEATERS
TO OTHER WCA GEAR
EXPLOSION S-1507
TORPEDO AND EXPLOSION SIMULATOR
ELAPSED TIME INDICATOR AT INSTRUCTOR'S POSITION
POSITION INDICATOR M-1402
MOTOR B-1201
POSITION TRANSMITTER R-1210
CAM SHAFT
WATER NOISE
TO OTHER WCA GEAR
SOURCE OF DC VOLTAGE WITH RANDOM INTENSITY VAR
60 KC PLUS FREQUENCY TO WHICH RECEIVER IS TUNED
SYNCHRO G-1804
JK TRAINING MOTOR
POSITION TRANS-MITTER R-1801
JK RED TARGET
FIXED COIL
JK BLUE TARGET OB
SYNCHRO G-1803
OB TRAINING MOTOR
POSITION TRANS-MITTER R-1802
SYNCHRO G-1801
SYNCHRO G-1802
SEARCH UNIT
RED TARGET RELATIVE BEARING
TO OTHER SEARCH UNITS
TO OTHER SEARCH UNITS
BLUE TARGET RELATIVE BEARING
TO BEARING INDICATORS AT INSTRUCTOR'S POSITION
OWN TRUE BEARING
TORPEDO PROBLEM S-1505
ON
OFF
SYNCHRO G-1203
SYNCHRO G-1402
SYNCHRO G-1401
COMPASS CARD
RING DIAL
RED TARGET BEARING REPEATER UNIT AT INSTRUCTOR'S POSITION
DIFFERENTIAL
RED TARGET BEARING CAM
SYNCHRO G-1201
SYNCHRO G-1601
SYNCHRO G-1602
SYNCHRO G-1202
BLUE TARGET BEARING REPEATER UNIT AT INSTRUCTOR'S POSITION
OWN BEARING CAM
RED TARGET
OWN
BLUE TARGET
TO OTHER SEARCH UNITS
BLUE TARGET BEARING CAM
DOPPLER CAM
BLUE TARGET RANGE CAM
RED TARGET RANGE CAM
TORPEDO CAM
SINGLE PING ECHO MIXER (NORMALLY BIASED TO CUT OFF)
ECHO DELAY VAR WITH RANGE
R-1208
60 KC PLUS DOPPLER
OSCILLATOR 60KC PLUS DOPPLER
SINGLE PING ECHO
RED TARGET INTENSITY VAR WITH RANGE
R-1207
S-1506 WATER CONDITIONS
MEDIUM
GOOD
BAD
R-1205
WATER NOISE INTENSITY VAR WITH OWN SPEED
MIXER
R-1202
BLUE TARGET INTENSITY VAR WITH RANGE
S-1207
MIXER
RANDOM DC VOLTAGE
ENEMY ECHO RANGING MIXER (NORMALLY BIASED TO CUT OFF)
ENEMY ECHO RANGING SIGNALS
RED TARGET SCREW SOUNDS AMPLIFIER
MIXER
RANDOM NOISE GENERATOR
OWN SCREW SOUNDS AMPLIFIER
BLUE TARGET SCREW SOUNDS AMPLIFIER
MOTOR B-1204
POSITION TRANSMITTER R-1209
POSITION TRANSMITTER R-1203
OSCILLATOR
17KC
27KC
OFF
ENEMY PING FREQUENCY S-1502
GAS TUBE SWITCH
PLATE SUPPLY
ENEMY PING INTERVAL
R-1506
RED TARGET SCREW SOUNDS GENERATOR
PHOTO ELECTRIC CELL
ROTATING DISK
LIGHT SOURCES
SCREW SELECTOR RED TARGET
S-1503
PROPELLER RPM VAR WITH SPEED
SPEED CHANGER
R-1206
RED TARGET SCREW SOUNDS INTENSITY VAR WITH SPEED
OWN SCREW SOUNDS GENERATOR
ROTATING DISK
PHOTO ELEC CELL
LIGHT SOURCE
PROPELLER RPM VAR WITH SPEED
SPEED CHANGER
OWN SCREW SOUNDS INTENSITY VAR WITH SPEED
R-1204
BLUE TARGET SCREW SOUNDS GENERATOR
ROTATING DISK
PHOTO ELECTRIC CELL
LIGHT SOURCES
S-1504
PROPELLER RPM VAR WITH SPEED
SPEED CHANGER
BLUE TARGET SCREW SOUNDS INTENSITY VAR WITH SPEED
R-1201
125V AC
T-504
POSITION INDICATOR M-1401
POSITION INDICATOR M-1601
RED TARGET
BLUE TARGET
RANGE INDICATORS AT INSTRUCTOR'S POSITION
RED TARGET SPEED CAM
OWN SPEED CAM
BLUE TARGET SPEED CAM

FIGURE 19. Functional block diagram of group listening teacher.

search unit. Own-screw sounds are applied to two fixed coils, while the red and blue target signals are fed to separate movable coils the physical positions of which are controlled with respect to the fixed coils by the relative bearing synchros G-1801 and G-1802. The combined signals fed to the WCA receiver inputs are obtained from series-connected movable coils, separate pickup coils being used for each target. The pickup coils are moved in relation to the target and to the fixed coils by means of d-c training motors which are controlled by the projector training circuits in the WCA equipment. Thus, for example, when the JK operator moves his training hand lever, the JK training motor in the search unit will rotate the JK pickup coils; the intensity of his own screw sounds and of the target signals applied to the JK receiver will then depend on the position of the pickup coils with respect to the fixed coils (JK projector bearing) and the target coils. By proper mechanical and electrical design, the overall signal pickup characteristics of the search unit are made to simulate those of actual projectors in a realistic manner. Each training motor drives (1) a position transmitter through which the projector bearing is reproduced on the projector indicator panel at the instructor's position and (2) a synchro-generator which transmits the projector bearing to a ring dial, or "bug," in the WCA equipment.

Echo-Ranging Signals. Provision is made for the simulation of echo-ranging signals by the red target on a frequency of 17 or 27 kc. The choice of frequency is made by means of the enemy ping frequency switch S-1502 on the target-noise control panel. The output of the oscillator which produces the enemy echo-ranging signals is fed to one grid of a mixer tube, the tube normally being biased to the cutoff point. The reduction of the bias to a value which will permit the mixer to produce an output signal is controlled by a gas-tube switch. When S-1502 is in the off position, the plate circuit to the gas tube is open and the mixer is cut off. The plate circuit is closed when S-1502 is in either the 17 kc or 27 kc position, and the gas-tube switch then intermittently removes the bias from the mixer at a rate determined by the setting of the enemy ping interval control R-1506. By means of this control, mounted on the target-noise control panel, any keying interval between 500 and 3,500 yd may be simulated. The cutoff bias is gradually restored (and the output signal intensity gradually decreased) by means of a resistance-capacity delay network, thus simulating the delay of an echo-ranging signal with time. The intensity variation of the reverberations is simulated by varying the conductance of the mixer; the potential of one grid of the mixer is varied in a random manner with a d-c voltage obtained by rectifying random noise. The mixer output, then, is a realistic enemy echo-ranging signal and is fed to the search unit, along with the red target screw sounds, through resistor R-1207, which provides for intensity variation with range.

Any one of the five QB operators may range on the red target, the choice being made by means of the single ping QB switch S-1501 on the target noise control panel at the instructor's position. This switch connects both the range indicator keying circuit and the local oscillator in the QB receiver to a mixer which is normally biased to cutoff. The mixer is also provided with a 60-kc signal from an oscillator (shown in the upper right-hand portion of Figure 19) and with random d-c voltage. When the range indicator keying circuit is closed, the cutoff bias is overcome and a mixer output which simulates realistic single-ping reverberations is obtained at the frequency to which the QB receiver is tuned. Since, in practical cases, the reverberations heard are independent of the projector bearing, this signal is fed directly to the QB receiver input (through a section of S-1501). A resistance-capacity delay network gradually restores the mixer bias to cutoff in the manner described in the previous paragraph.

The range indicator keying circuit and the local oscillator in the QB receiver are also connected from S-1501 to another mixer from which the single-ping echo is obtained. This mixer is provided with a signal whose frequency is 60 kc plus the amount of doppler consistent with the problem; the frequency of the oscillator is controlled by the doppler cam over a range of ±300 c. The mixer output, therefore, is at the frequency to which the QB receiver is tuned, plus the appropriate amount of doppler. The mixer is normally biased to cutoff. When the range indicator keying circuit is closed, a delay period is started which is made proportional to the red target range by R-1208 (driven by the red target range cam). At the end of this period, the mixer cutoff bias is momentarily overcome, and an echo signal is produced at the mixer output. This signal is fed with the other red target signals to the search unit through R-1207, since the intensity of the received echo is a function both of target range and of projector bearing.

Torpedo Noise. If a particular problem calls for the firing of a torpedo, switch S-1207 will be operated at the appropriate time by the torpedo cam. The blue target screw sounds are then replaced by the simulated torpedo sounds (generated electronically) through the torpedo problem switch S-1505 on the target-noise control panel at the instructor's position. By opening this switch, the torpedo sounds can be eliminated when desired. The torpedo sounds are fed to the search units through R-1202, which provides intensity variation with range. Explosion of the torpedo may be simulated by closing explosion switch S-1507 on the target-noise control panel. The explosion sounds are assumed to be nondirectional, hence are fed directly to the inputs of the JK and QB receivers.

Power Supply. Direct current of 110 volts is necessary to supply filament heating power and plate voltage throughout the system, but all other components are operated by 115-volt alternating current. Detailed information on the operation of the circuits may be found in the preliminary instruction manual listed in the bibliography for this chapter.

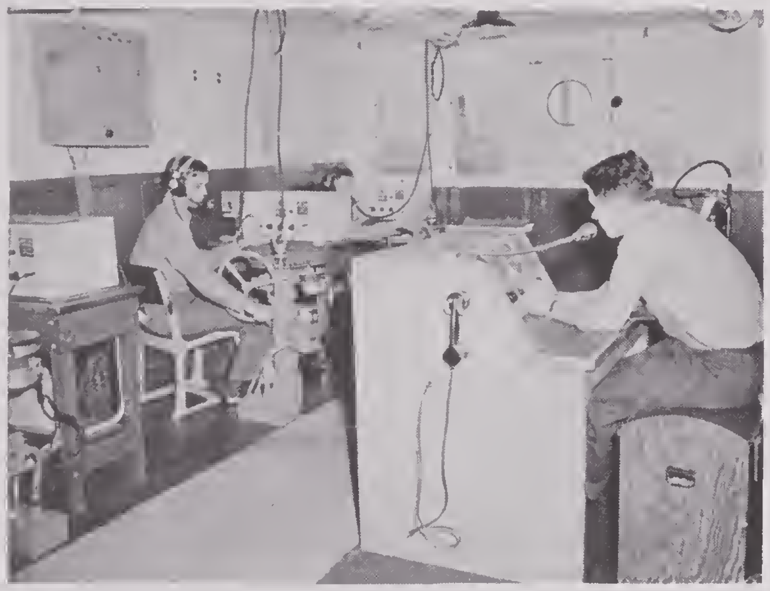


FIGURE 20. Barge monitoring equipment.

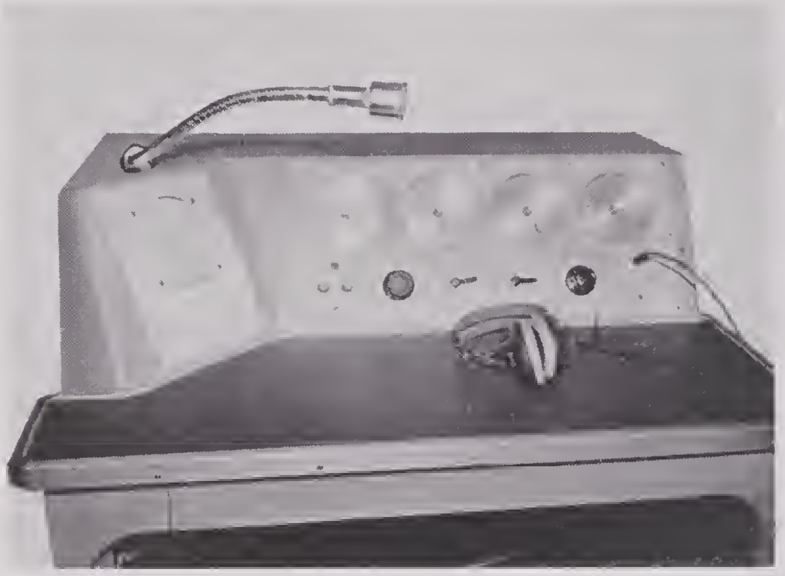


FIGURE 21. Instructor's console, barge monitoring equipment.

Barge Monitoring Equipment

Barge monitoring equipment, developed by CUDWR-NLL, is a device which enables one instructor to monitor four JP equipments installed in a Navy training barge. The monitor consists of the instructor's console, a main control box, and four students' control boxes (one on each JP amplifier). The console includes repeater dials following the pelorus topside, and a talk-back system which permits the instructor to communicate with the operators individually or all four at once. The instructor may also pick up the output of any JP amplifier to check the signal being received by the student. A hand telephone set and E call circuit connect the console to the pelorus watch topside. The main control box carries the intercom amplifier and the station selector relays. The students' control boxes simulate the operator's control of the NL-119 JP intercom system.

Chapter 15

TRAINERS AND DEMONSTRATORS FOR SUBMARINE OFFICERS

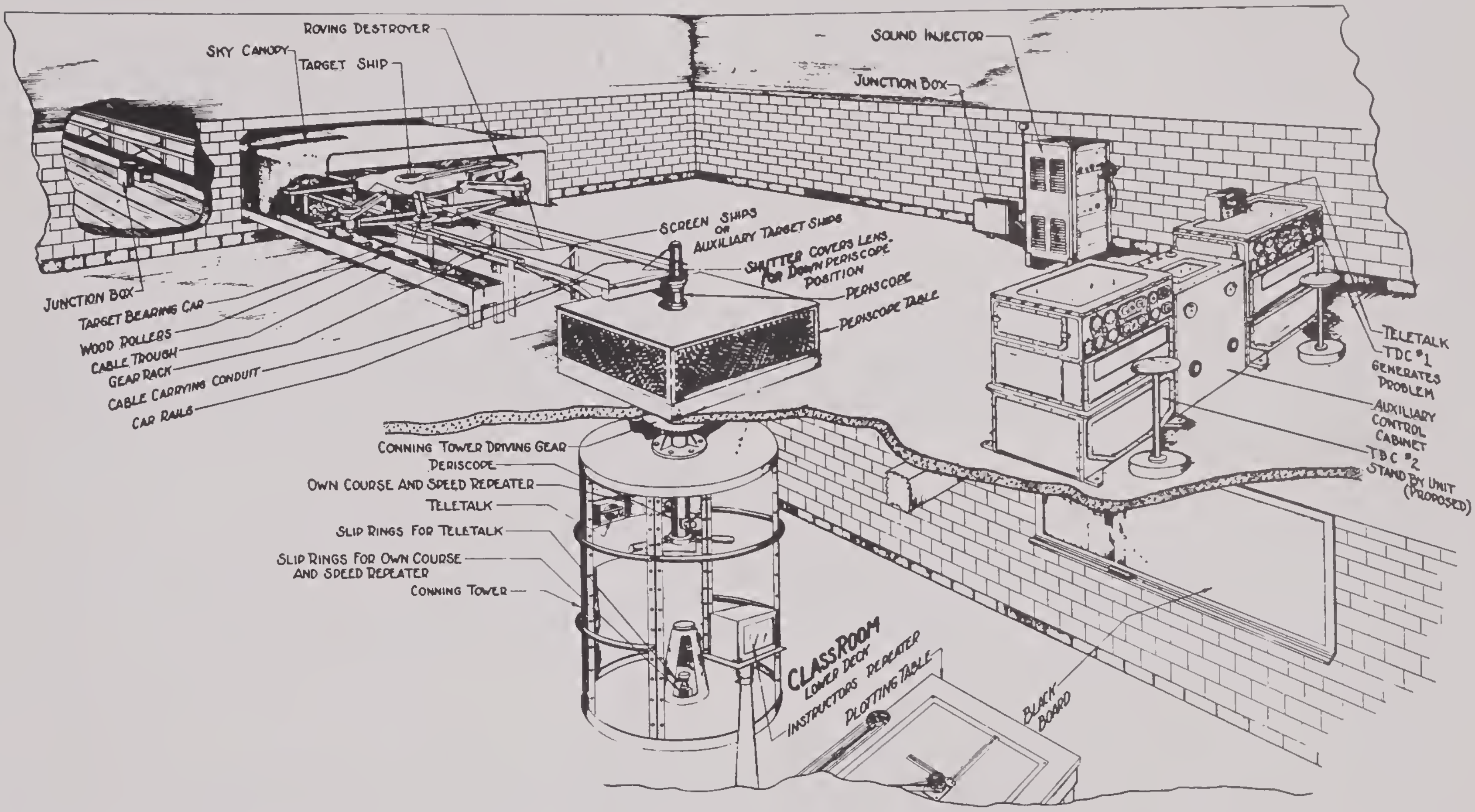

ROVING DESTROYER
SKY CANOPY
TARGET SHIP
SOUND INJECTOR
JUNCTION BOX
SCREEN SHIPS OR AUXILIARY TARGET SHIPS
SHUTTER COVERS LENS FOR DOWN PERISCOPE POSITION
PERISCOPE
PERISCOPE TABLE
JUNCTION BOX
TARGET BEARING CAR
WOOD ROLLERS
CABLE TROUGH
GEAR RACK
CABLE CARRYING CONDUIT
CAR RAILS
TELETALK
TDC #1 GENERATES PROBLEM
AUXILIARY CONTROL CABINET
TBC #2 STAND BY UNIT (PROPOSED)
CONNING TOWER DRIVING GEAR
PERISCOPE
OWN COURSE AND SPEED REPEATER
TELETALK
SLIP RINGS FOR TELETALK
SLIP RINGS FOR OWN COURSE AND SPEED REPEATER
CONNING TOWER
CLASSROOM LOWER DECK
INSTRUCTORS REPEATER
PLOTTING TABLE
BLACK BOARD

FIGURE 1. Modified Mark I conning officer attack teacher as installed at the U.S. Navy Submarine Base, New London, Connecticut.

Conning Officer Attack Teacher Modification

The conning officer attack teacher modification, developed by CUDWR-NLL, is an extensive redesign of the Mark I attack teacher used in the training of submarine conning officers and their associated personnel. The original model consisted essentially of a conning tower and periscope associated with a single manually controlled target ship model mounted on a target-bearing car. The modifications include the provision of multiple targets, new and variable lighting effects, repeater units in the conning tower and classroom, simulated underwater sounds, and radar patterns. The problem presented is controlled from a Mark I torpedo data computer, which likewise underwent some modifications.

EXCEPT FOR SOME MINOR alterations, the Mark I attack teacher, originally constructed in 1920, had not been modernized. Interim improvements in sonar gear, the introduction of radar, and the overall demands of submarine warfare in World War II made a redesign imperative.

As modernized, the conning officer attack teacher makes it possible to reproduce in the classroom the conditions of a submarine attack from the instant the enemy ship (or ships) is sighted until the torpedoes are fired. It is thus of great assistance in the training of prospective submarine commanding officers, approach officers, and fire control parties.

As shown in Figure 1, the equipment is installed in a classroom with two decks. Training sessions take place on the lower deck, where a submarine conning tower rotated by a power drive is the student's station during a practice run. A repeater unit and plotting table on this deck enable the instructor to follow the course of the problem and to analyze the trainee's performance.

The periscope of the conning tower is brought through the floor of the upper deck, where it may be focused on a target convoy made up of miniature ships mounted on a target bearing car similar to the spokes of a wheel. The target bearing car is driven on a track toward or away from the periscope to simulate closing or opening range. The miniature ships are also maneuverable in relation to one another. Light conditions can be varied during the course of a problem from brilliant sunlight to any degree of darkness desired, including red sunrise and red sunset.

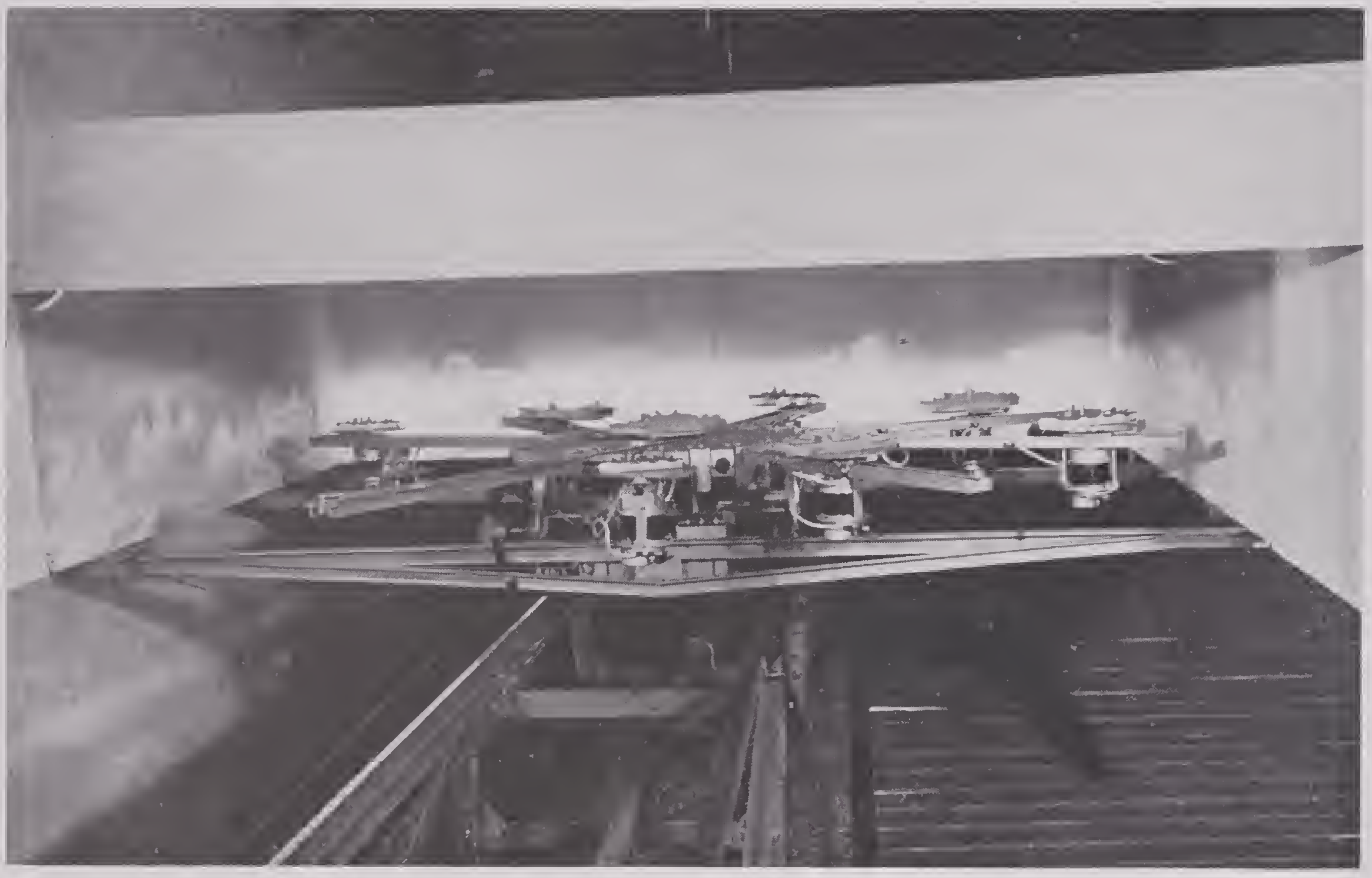


FIGURE 2. Target bearing car and sky canopy.

The torpedo data computer which generates the problem, the auxiliary control cabinet, and the sound injector are also located on the upper deck. The generated data are picked up through synchro units and are used to control (1) the motion of the target bearing car on the track and hence the simulated range; (2) the bearing and angle-on-the-bow of the central target ship; (3) the bearing and angle-on-the-bow of the various screen ships; (4) the relative angular position of the screen ships with respect to the target; (5) the position in azimuth of the simulated conning tower and hence the relative bearing of the target with respect to the submarine; (6) the apparent sound range and bearing of the target ship and the variation of background water noise caused by changes in own-ship's speed.

By using this equipment, a student is able to observe an enemy ship or convoy through a standard periscope. He can then maneuver his submarine through the approach and attack phases of the problem to attain a favorable firing position. Actual conditions are simulated in the speed and relative bearing of the target ship or ships, speed and course of the attacking submarine, and the changing range caused by the interaction of these factors.

15.1 DESCRIPTION

Target Bearing Car. The target bearing car, shown in Figure 2, carries all target and screen ships of the simulated enemy convoy. Provision is made for mounting as many as seven auxiliary ships on arms supported by the carrier plate, one roving destroyer on a special arm likewise supported by the carrier plate, and one central target ship on a shaft independent of the carrier plate. All seven ships may be maneuvered together as screen ships, or up to four of them may be used as auxiliary target ships. Should it be considered desirable to use all seven arms for screen ships and yet have auxiliary target ships, four new arms may be made and mounted in sockets and brackets provided on the carrier plate.

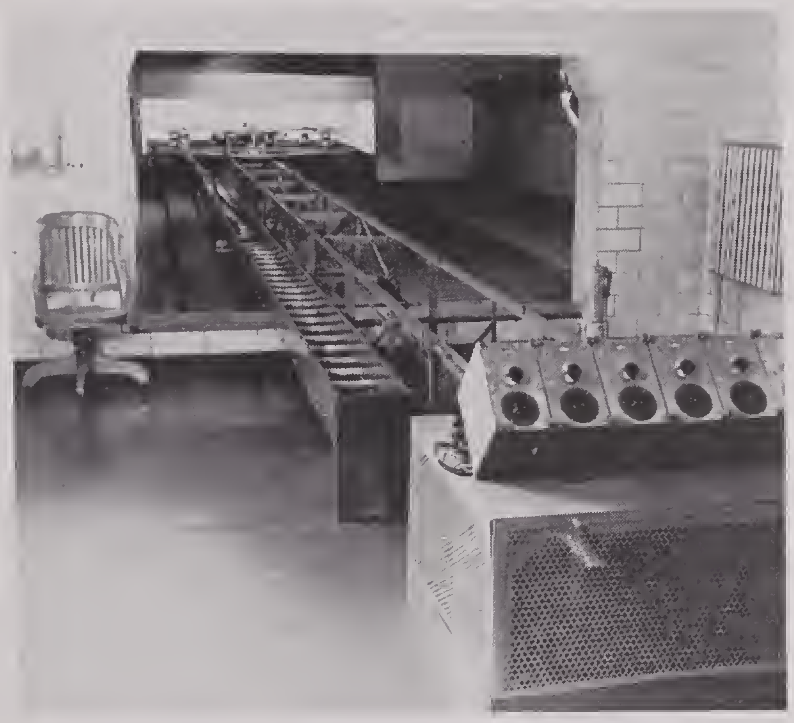


FIGURE 3. Track for target bearing car and periscope support table.

Rotation of the plate carrying the central target ship is servo-controlled from the signals given out by the angle-on-the-bow synchro in the torpedo data computer. By the use of synchro differentials and followers actuated from the torpedo data computer, the screen and auxiliary ships (including the four extra models, if these are added) will automatically maintain the same angle on the bow as the center target ship or, by the operation of a switch, maintain automatically a 000-degree angle on the bow independent of the center target. If it is desired, a lead or lag may be introduced into their relative positions through the auxiliary control cabinet. They can also be made to start and maneuver for position ahead of the target ship as it changes course. The roving destroyer is separately maneuvered from the auxiliary control cabinet.

The target bearing car travels along a 75-ft track directly in front of the periscope (see Figure 3). (Some installations may use a $37\frac{1}{2}$-ft track with proportionally smaller ship models.) The car's distance and speed of travel are determined by the range and closing rate of the submarine and target ship and are controlled by the range synchro-generator in the torpedo data computer, which feeds through a control transformer and a servo-amplifier to the driving motor of the car. The car travels on four wheels, two of which, on one track, are grooved and two, on the other track, wide flanged. This keeps the car aligned with the axis of the track and provides lateral stability.

Submarine Course and Speed Repeater. In order that the approach officer may know the course and speed of his own boat at all times, an own-course and speed repeater (Figure 4) is mounted in the conning tower. This consists of two 5-in. dials mounted in a small cabinet and driven by two standard 5F synchro followers. These are actuated by own-course and own-speed synchro generators in the torpedo data computer and maintain the same readings on the repeater dials as those on the corresponding dials of the torpedo data computer. The re-

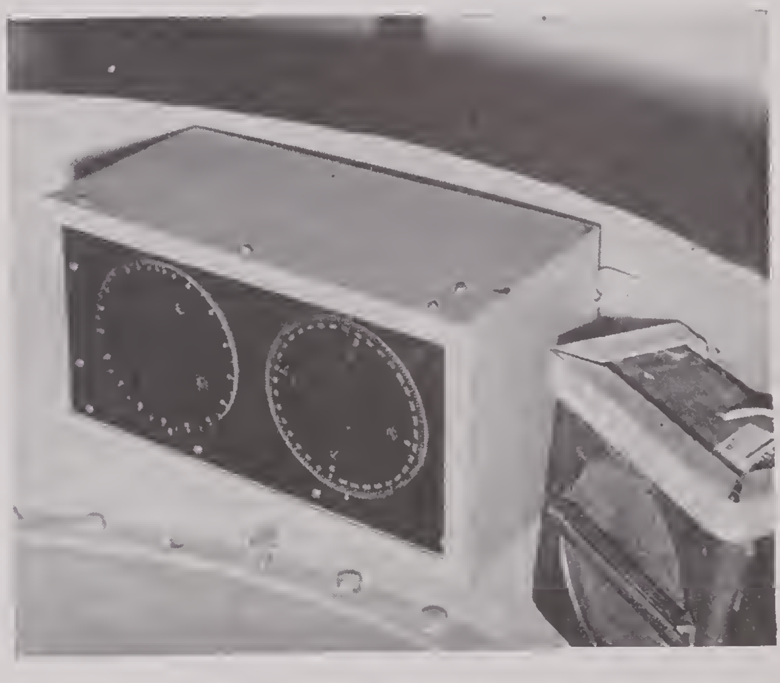


FIGURE 4. Own-course and speed repeater in conning tower.

peater dials are engraved, filled with luminous paint, and illuminated by lamps in the cabinet. This system of illumination is employed throughout the trainer wherever dials are installed.

Instructor's Repeater. An instructor's repeater is provided to relay certain information from the torpedo data computer to the instructor in the classroom on the lower deck. It consists of a small cabinet in which are mounted four dials showing relative bearing, angle-on-the-bow, target speed, and range at all times during the course of the problem. The dials in this repeater are driven by four 5F synchro followers actuated by corresponding synchro-generators in the torpedo data computer.

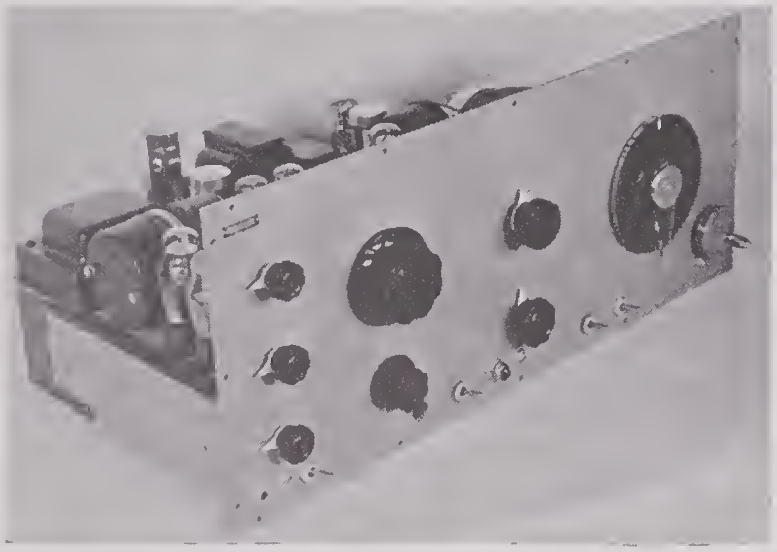


FIGURE 5. Sound injector.

Auxiliary Control Cabinet. The auxiliary control cabinet provides means for controlling the angle-on-the-bow of the screen ships or their rotation around the center target manually or automatically. It also provides control of the roving destroyer and the lighting effects inside the sky canopy. The left-hand crank controls the rotation of the carrier plate and the degree of rotation can be read on the left dial on top of the cabinet. The right-hand crank controls the course of the screen ships relative to the center target with the right-hand dial showing the number of degrees the course has been changed. The two lower knobs control the Variacs which produce the various lighting effects. Across the top of the cabinet is a bank of switches which control lights and mechanisms for either automatic or manual operation. A switch is also provided for switching in a second Mark I torpedo data computer (if available) in case of failure of the first, and a Variac for controlling the speed of the roving destroyer.

Power Drive for Conning Tower. The power drive for the conning tower is located under the periscope support table. It operates on a signal from the relative bearing synchro in the torpedo data computer and rotates the conning tower as directed. Power is obtained through the use of an amplifier, an amplidyne, and a d-c motor. This motor drives a small spur gear which, in turn, drives the large gear on the conning tower shaft. Electrically, the directing signal from the relative bearing synchro is fed into a synchro-control transformer, which then drives the amplidyne amplifier. The signal from the amplifier supplies the control fields of a motor generator which in turn supplies armature current for the main amplidyne motor. When there is no signal from the relative bearing synchro, the generator has no control field current and hence no output. Under this condition the rotor of the amplidyne motor is stationary.

Periscope Support Table. At the point where the periscope comes through the deck, a grille-enclosed steel table is located. This table supports the periscope and houses the amplidyne power unit for driving the conning tower. Since it is of simple construction and may have to be altered to fit individual installations, it is constructed "on location."

Sky Canopy and Lighting Effects. In order more nearly to simulate actual attack conditions, a skyline background and variable conditions of light and dark are provided about the enemy convoy. This is accomplished through the use of a large plywood canopy, shown in Figure 2. The canopy is open at the front in order not to interfere with periscope vision and is painted with clouds and blue sky at the rear as a background for the target ships. A bank of lights at the front and another at the rear of the canopy are controlled by Variacs in the auxiliary control cabinet to provide different lighting effects.

Sound Injector. In order to inject into the conning tower sonar gear sounds which would simulate realistically the problem presented by the motion of the target ship model, an electronic sound injector, shown in Figure 5, was developed. It introduces into WCA or JP-1 sonar equipment sounds closely resembling those of a target ship and also simulated water noise. The artificial echo representing the target ship can be "placed" at a range exactly corresponding with the model ship's position on the target bearing car in relation to the periscope. Further arbitrary and automatic adjustments, including provision for correct bearing indication via the echo, make it possible to produce a highly realistic sound situation.

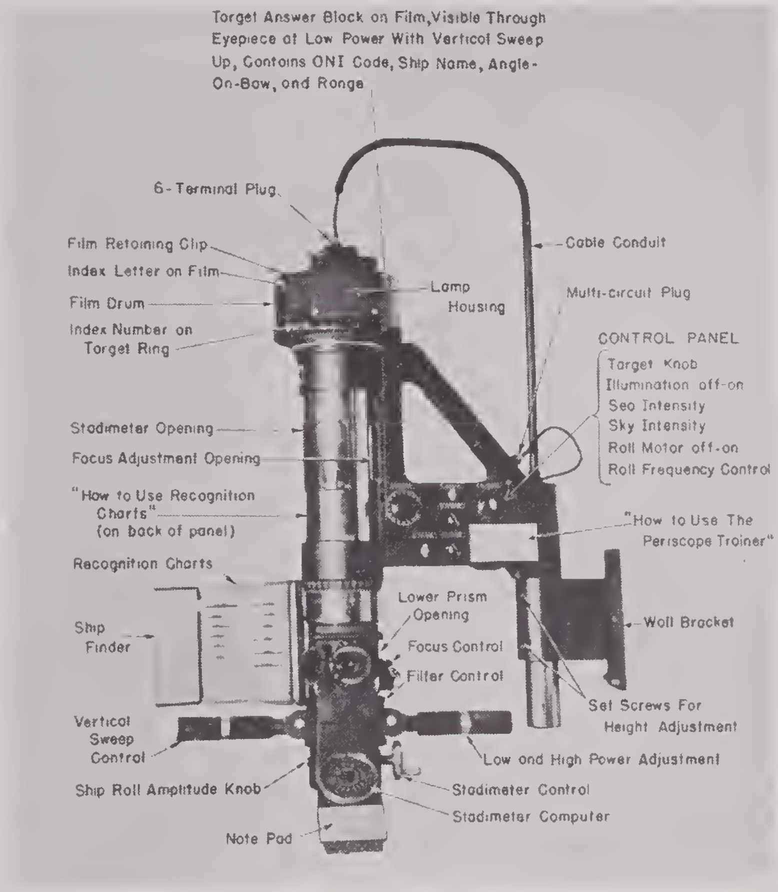

Target Answer Block on Film, Visible Through Eyepiece at Low Power With Vertical Sweep Up, Contains ONI Code, Ship Name, Angle-On-Bow, and Range
6-Terminal Plug
Film Retaining Clip
Index Letter on Film
Film Drum
Index Number on Target Ring
Lamp Housing
Cable Conduit
Multi-circuit Plug
CONTROL PANEL
Target Knob
Illumination off-on
Sea Intensity
Sky Intensity
Roll Motor off-on
Roll Frequency Control
Stadimeter Opening
Focus Adjustment Opening
"How to Use Recognition Charts" (on back of panel)
"How to Use The Periscope Trainer"
Recognition Charts
Ship Finder
Lower Prism Opening
Focus Control
Filter Control
Wall Bracket
Set Screws For Height Adjustment
Vertical Sweep Control
Low and High Power Adjustment
Ship Roll Amplitude Knob
Stadimeter Control
Stadimeter Computer
Note Pad

FIGURE 6. Overall view of periscope trainer, Mark III.

Periscope Trainer

The periscope trainer, developed by CUDWR-NLL, is a device for the elementary training of officers in ship recognition, judgment of bearing and angle-on-the-bow, and estimation of range by telemeter or stadimeter. It is a mock-up of the lower part of a submarine periscope and its operation is essentially the same as that of a standard periscope. Replacing the top of the periscope, however, is a circular drum in which are inserted film strips showing target ship images at various ranges and angles-on-the-bow. The images are back-illuminated by lamps contained in a housing which rotates with the periscope tube so that the illumination is always directly behind the field of view. The target drum is rotated by a hand control to change targets, or target positions. After identifying the target ship and estimating its angle-on-the-bow and range, the student can check his answers by tilting the vertical sweep in low power until an answer box above the ship image becomes visible.

Three models of the periscope trainer were designed. The third and final model, designated the Mark III periscope trainer, is shown in Figure 6. The lower part of the trainer duplicates the ocular end of a Type II Kollmorgen Corporation periscope in which the usual provisions are made for focusing, training, and reading bearings. Although the periscope has been reduced in length, its operation and optical properties are essentially the same as those of a standard periscope. As the synthetic model is trained through 360 degrees, the upper lens sweeps through a continuous photographic view of the sea. Ships of various types, ranges, and angles-on-the-bow are included in the transparent film, illuminated from behind. Targets are moved so that correct perspective is maintained for the supposed range. Own-ship's roll, variable in amplitude and period, is simulated.

Accompanying each trainer is a set of target ship films, consisting of 12 strips with 13 views on each strip. These cover 49 merchant vessels and 20 warships, all Japanese. Figure 7 is a contact print of a portion of film strip showing the answer boxes which, together with the recognition charts and instructions posted near the controls, enable a student officer to practice on the trainer alone and check his performance.

15.2 DESCRIPTION

The periscope trainer is an optical system contained in a three-part assembly which is made up of a periscope body tube, a periscope head casting, and a target ring at the top. This main assembly rotates in bearings attached to a support which is mounted on a wall bracket or table.

Optical System. The optical system consists of a ray filter, eyepiece lens, eyepiece prism, telemeter scale, stadimeter lenses, special low-power objective, special high-power objective, upper prism, film drum, target film, heat absorbent glass, diffusing screens, and lamps. A schematic diagram of the optical system is shown in Figure 8.

Illumination. The lamp housing contains two 110-volt, 25-watt, candelabra-base, tubular-type lamps, each 5¼-in. long. These are controlled by rheostats located on the side of the trainer. The horizontal arrangement of the lamps, one above and one below the horizon line, permits illumination of either the simulated sea or sky with varying intensities to represent various visibility conditions.

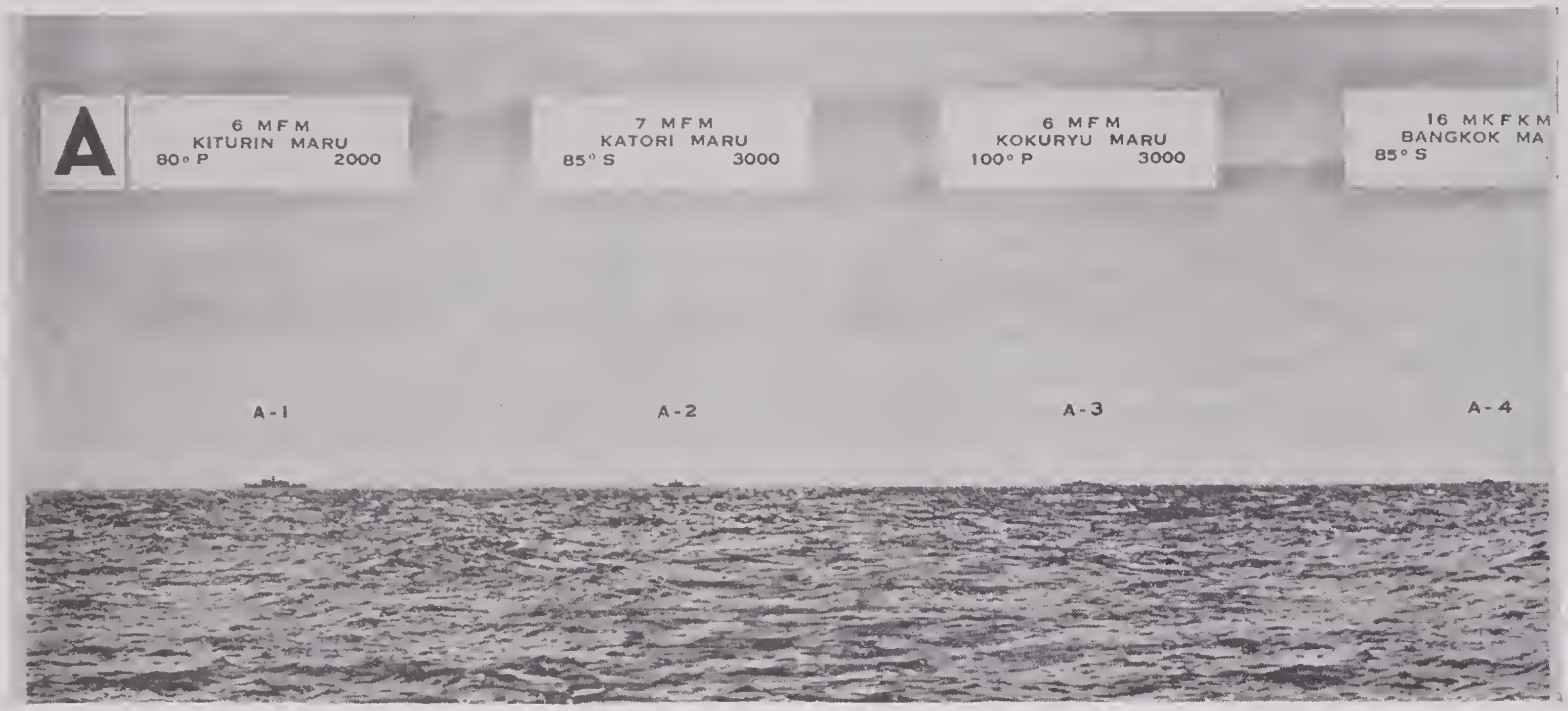


FIGURE 7. Contact print of portion of film strip.

Target Film. The telemeter scale has 32 scale divisions. Since the field on the target at high power is ¾ in. in diameter, one of the divisions on the telemeter scale will subtend 0.023 in. Ranges from 1,500 to 6,600 yd are covered by the film strips. From the range formula, a ship with a 100-ft mast will subtend one division at 7,640 yd; therefore, the ship images will range in size from about 1/64-in. mast height to a maximum of 2½ in. for extremely close range.

In order to reproduce faithfully target images to this small and exact scale, a special fine-grained film is required (Eastman Kodak No. 548). Special developing techniques were found necessary and were perfected by the producer, Kellogg and Bulkeley, in order to obtain the necessary gradation with the fine-grain resolving power desired.

The horizon on the film strips is continuous and is located approximately one-third the distance from the bottom of the 4-in. printed portion of the film. The ships are so spaced that only one ship is in the field of view when the image is centered. The image of a merchant ship as seen through the periscope trainer in high power is shown in Figure 9. It should be realized that some detail is lost in the reproduction of these prints from the positive transparency.

The film strips are systematically arranged, films A, B, C, D, and E showing 49 Japanese merchant vessels at moderate ranges (1,500-4,000 yd) and angles-on-the-bow close to 90 degrees (65 to 125 degrees). Films F and G show 20 Japanese warships at similar ranges and aspects. These views lend themselves to elementary training in identification and range determination. Films H, I, J, K, and L show the same ships at longer ranges (1,900-6,600 yd) and include aspects which make recognition more difficult.

The films associated with the Mark I and II trainers were different in a number of ways. They did not include the "answer box," the most important change. Without this feature, self-training was extremely difficult. Six additional film strips in the Mark I and II set attempted to portray convoys, but the simultaneous viewing of several ships at different ranges was not realistically portrayed, and the intended training was not only ineffective but possibly harmful. These convoy films were therefore eliminated in the Mark III set. In the rearrangement of the films for the Mark III unit, instances of poor reproduction were eliminated and rephotographed, and additional views were included to give a more balanced distribution of the various ships at different ranges and aspects.

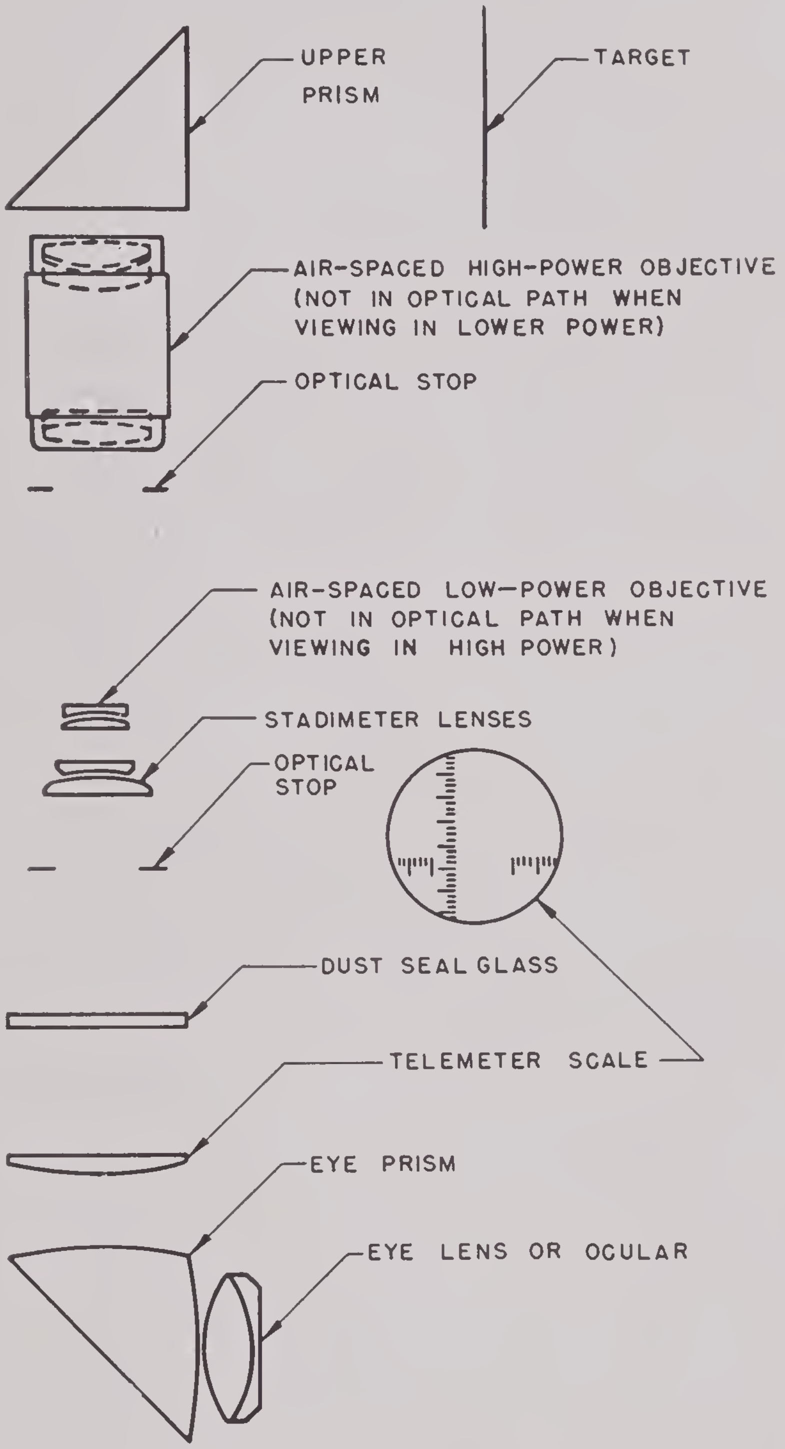

UPPER PRISM
TARGET
AIR-SPACED HIGH-POWER OBJECTIVE (NOT IN OPTICAL PATH WHEN VIEWING IN LOWER POWER)
OPTICAL STOP
AIR-SPACED LOW—POWER OBJECTIVE (NOT IN OPTICAL PATH WHEN VIEWING IN HIGH POWER)
STADIMETER LENSES
OPTICAL STOP
DUST SEAL GLASS
TELEMETER SCALE
EYE PRISM
EYE LENS OR OCULAR

Figure 8. Optical system schematic.

Undoubtedly, as further experience is gained and perhaps as training needs change, additional or different film strips will be desired. These may readily be produced, since the pioneering work in this rather unusual photographic problem has been completed.

Vertical Sweep and Simulated Ship Roll. The upper prism cell is pivoted and carries an extended arm to which is attached a long connecting rod. This rod is brought down through the periscope tube, and its lower end is pivoted to the center of an equalizing lever. One end of this equalizer is attached to an eccentric on a crank driven by a motor. The crank pin and the eccentric each have the same swing and the eccentric is rotatable through 180 degrees on the crank pin. Turning the eccentric on the crank pin permits continuously adjustable ship roll from zero to approximately 8 degrees list or 16 degrees total roll. Markings on the eccentric permit setting to any desired roll. The other end of the equalizer is connected to the left-hand training grip through a pitman and a crank on the training grip shaft. The rotation

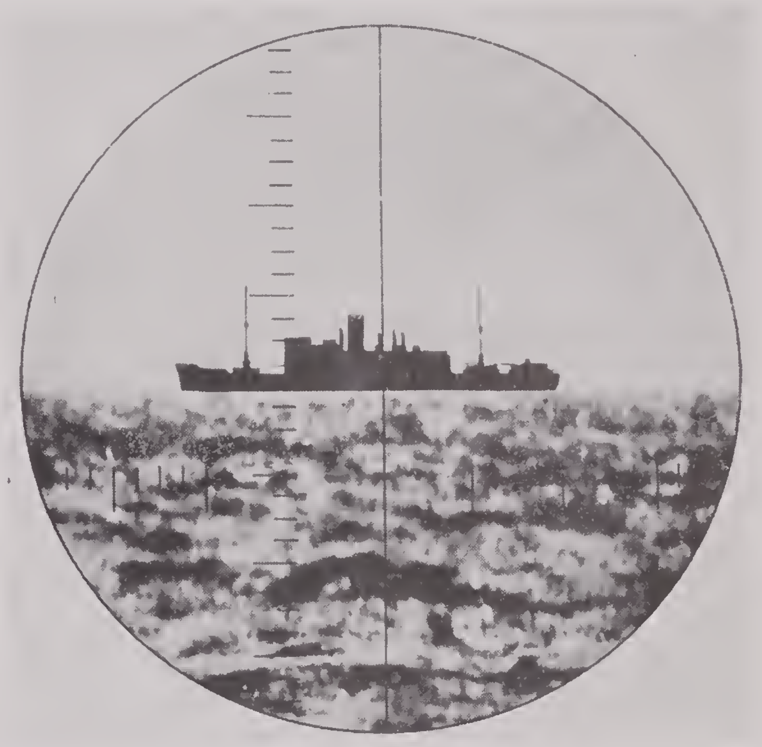


Figure 9. Image of merchant vessel with periscope in high power.

of the motor-driven crank tilts the upper prism simulating ship roll, which may be compensated for by equal and opposite operation of the vertical-sweep control. The ship-roll amplitude dial rotates slowly in operation, but it can be conveniently adjusted in motion if so desired. A Variac control on the side of the trainer permits adjustment of the frequency of roll. Figure 10 is a schematic of the electric system.

Horizontal Training. Training or sweep in horizontal azimuth is the same as with a standard periscope and is effected by rotating the entire periscope assembly by means of the training handles. In order to require the student to use the periscope-training handles, the target ring can be rotated to any desired position by means of a dial which is located on the bearing support frame. This has the same effect as if the submarine had changed course and makes it necessary to train the periscope on the target again.

Stadimeter. By means of a stadimeter, the water line of a vessel in one image can be brought into apparent contact with the masthead as seen in the other image. The amount of displacement necessary to effect this is translated on the stadimeter dials to the range of the vessel as read against the estimated or known distance between masthead and water line. In the type of stadimeter provided with the periscope trainer, the images are displaced vertically only. The lenses used for the dual images are so constructed that in the zero, or observing position, the combination of three lenses combine to form a plain window. Operation of the stadimeter knob displaces the two movable lens halves by means of gearing and a cam and at the same time rotates the stadimeter dial. When the lens halves are displaced, they become in effect two optical wedges which displace half of the rays from the objective upward and the other half downward. This results in two images, each of which is approximately half as brilliant as the combined image. Stops are provided on the stadimeter knob shaft which limit the movement of the dial to approximately 382 degrees.

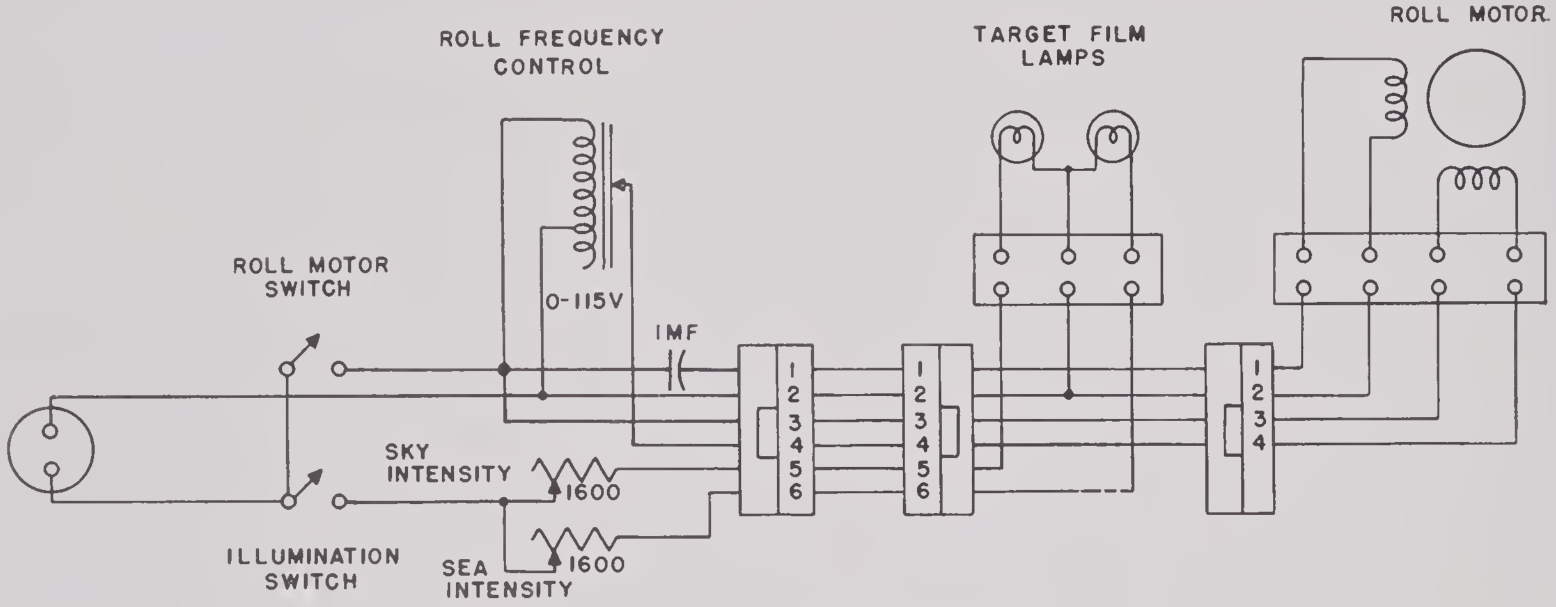
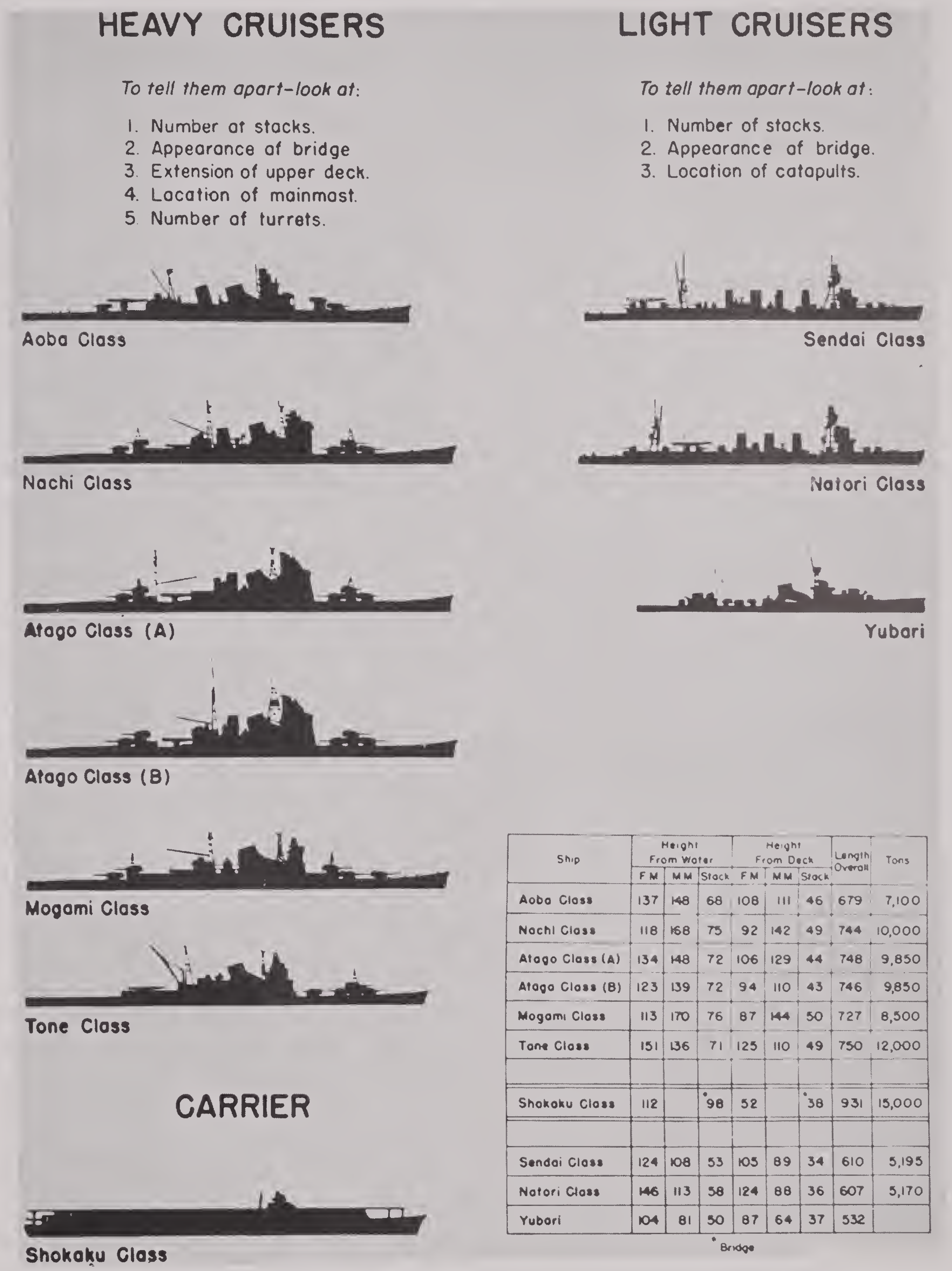


FIGURE 10. Electrical schematic for the periscope trainer.

Ship Finder and Recognition Charts. As shown in Figure 6, a ship finder and set of recognition charts are attached to the trainer for instant use by the student. A sample chart is reproduced in Figure 11. The instructions for using the charts are posted on the back of the trainer. The charts give the student immediate access to the information necessary for identification and, once the ship's name is known, mast and stack heights for ranging are also available. Length and tonnage are also shown, so that the student may check his estimates of these figures. The position of the charts is such that they may be used by the student himself, by a mate when teams of two work together, by the instructor, and even by a small group. It may be seen in the data associated with the recognition charts that some of the heights and lengths differ slightly from



HEAVY CRUISERS

To tell them apart–look at:

1. Number of stacks.
2. Appearance of bridge
3. Extension of upper deck.
4. Location of mainmast.
5. Number of turrets.

LIGHT CRUISERS

To tell them apart–look at:

1. Number of stacks.
2. Appearance of bridge.
3. Location of catapults.

CARRIER

Aoba Class
Sendai Class
Nachi Class
Natori Class
Atago Class (A)
Yubari
Atago Class (B)
Mogami Class
Tone Class
Shokaku Class

Ship	Height From Water			Height From Deck			Length Overall	Tons
	F M	M M	Stack	F M	M M	Stack		
Aoba Class	137	148	68	108	111	46	679	7,100
Nachi Class	118	168	75	92	142	49	744	10,000
Atago Class (A)	134	148	72	106	129	44	748	9,850
Atago Class (B)	123	139	72	94	110	43	746	9,850
Mogami Class	113	170	76	87	144	50	727	8,500
Tone Class	151	136	71	125	110	49	750	12,000
Shokaku Class	112		*98	52		*38	931	15,000
Sendai Class	124	108	53	105	89	34	610	5,195
Natori Class	146	113	58	124	88	36	607	5,170
Yubori	104	81	50	87	64	37	532	

* Bridge

FIGURE 11. Sample recognition chart.

similar data for the same ships shown in the ONI. The measurements shown were scaled from the models photographed when it was discovered that the models were not all exactly in proper scale proportion as compared to the ONI data. The differences are not serious but had to be recognized if the actual ranges shown were to be determined correctly by telemeter fill and stadimeter computation.

Operating Instructions. In addition to the instructions posted on the trainer itself, an instruction and maintenance manual has been issued.[1] This manual contains a set of answer sheets for instructors to use in checking the students' observations and in selecting the targets, aspects, and ranges desired for training.

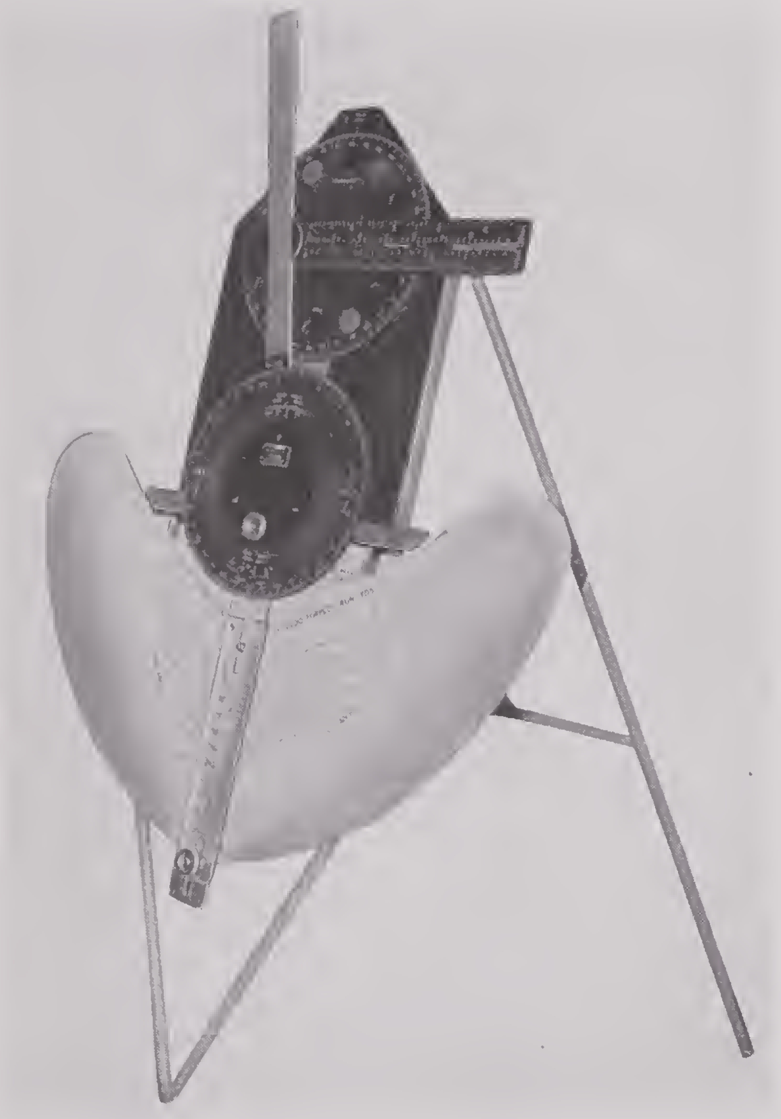


FIGURE 12. Torpedo angle solver demonstrator.

Torpedo Angle Solver Demonstrator

The torpedo angle solver demonstrator, developed by CUDWR-NLL, is an enlarged working model of the Mark VIII torpedo angle solver designed to demonstrate its correct use to groups of student officers. Data scales have been enlarged photographically to two and one-half times normal size, and other parts have been reproduced to scale.

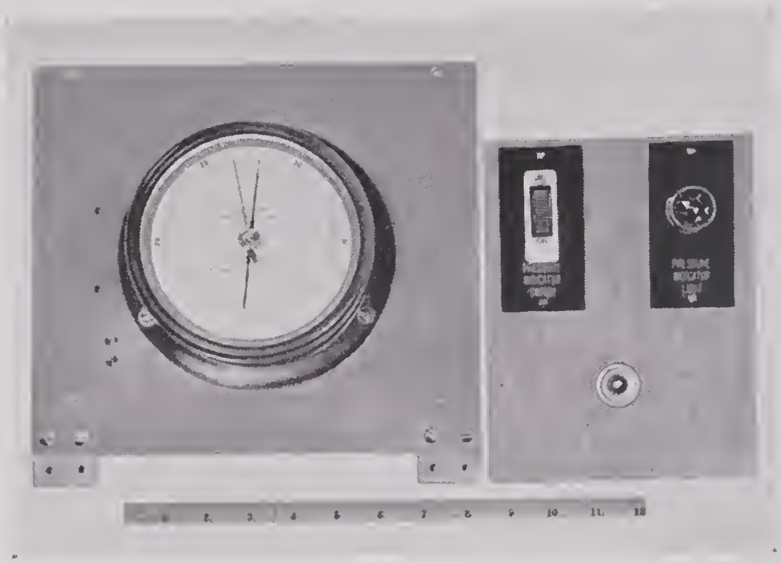


FIGURE 13. Submarine barometer simulator, front view.

The Submarine Barometer Simulator

The submarine barometer simulator was designed by UCDWR as an adjunct to the submarine diving trainer (Askania trainer) to reproduce the operation of a standard submarine barometer when the vessel is preparing to submerge. The main assembly is a modified Navy aneroid barometer. On a control panel are the pressure indicator off-on switch, the pressure indicator light, and the "diving alarm" push-button. Operation of the diving alarm push-button causes the barometer needle to indicate "normal pressure"; release causes indication of "pressure in the boat."

On board an actual submarine, the internal air pressure is increased slightly just before submergence to make sure that all openings to the outside atmosphere are closed. If pressure, as indicated by the barometer, fails to build up at this time, the diving officer is warned that diving is unsafe. Since simulation of this operation was provided in the submarine diving (Askania) trainer, the submarine barometer simulator was designed as an adjunct to the trainer.

15.3 DESCRIPTION OF CIRCUIT

The wiring diagram for the device is given in Figure 14. Operation is as follows. When the diving alarm pushbutton is actuated, the contacts of the Leach 1157 relay are opened. Opening of these contacts de-energizes the 33L15 actuator and a spring restores the on-off contacts on the Ward Leonard mechanical time-delay relay to the off or starting position. The simulated barometer needle is also coupled to the rotating arm carrying the on-off contacts of this relay, and restoration of this arm to the off position moves the barometer needle to the normal pressure indication point. This may be manually set at any value (ordinarily 29.6 in. of mercury). Release of the diving alarm pushbutton restores the circuit through the Leach 1157 relay if the pressure indicator switch is closed. The Telechron motor is energized and rotates the contact arm of the Ward Leonard relay. After a suitable time interval, which may be preset by means of an adjusting nut on the rear of the Ward Leonard relay, this rotation increases the barometer needle indicator by 0.3 in. of mercury, thus indicating "pressure in the boat," and also closing the on contact which lights the pressure indicator light. The Ward Leonard relay is so constructed that the Telechron motor winding is opened when the on contacts are closed. Operation of the diving alarm pushbutton restores the indicated pressure to normal, and the cycle is repeated.

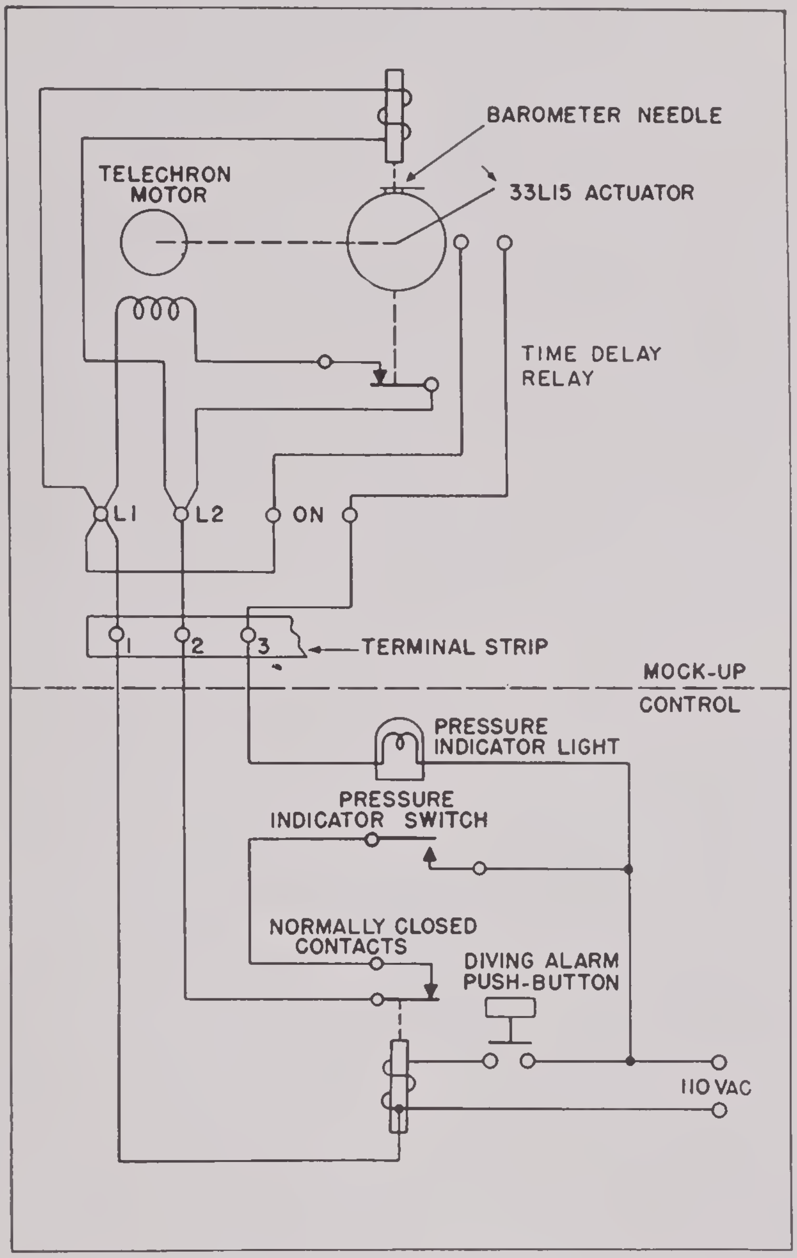


FIGURE 14. Electrical schematic for the barometer simulator.

If no pressure indication is desired, the pressure indicator switch is left in the off position; and if a pressure indication is desired with more time delay than is mechanically set into the Ward Leonard time-delay relay, the pressure indicator switch may be operated at any time after the diving alarm pushbutton has been actuated. The mechanical delay time will then be added to whatever manual delay time is used.

The Bathythermograph Simulator

The bathythermograph simulator [TBS], developed by UCDWR, is a device designed (1) to introduce automatically into the Askania diving trainer the changes in water density with depth caused by a specific temperature gradient and (2) to trace on the card of a submarine bathythermograph mockup the corresponding depth-temperature curve. Any desired depth-temperature pattern may be recorded on a master card for reproduction on the card of the bathythermograph simulator. A movable light-spot, photocell combination automatically follows the master card pattern and thereby gives temperature indications which are transferred to the temperature recording element of the bathythermograph mockup and to the "density" control shaft of the Askania trainer.

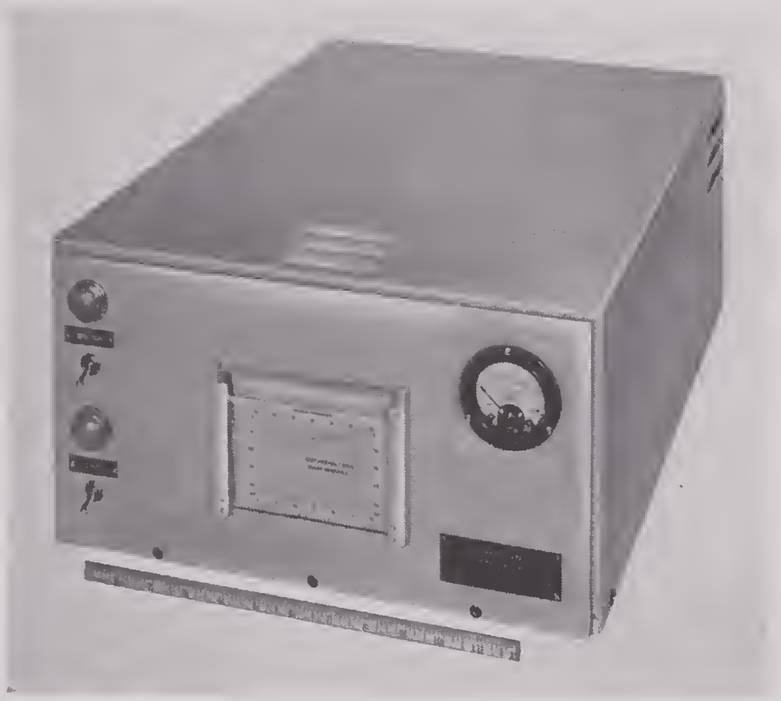


Figure 15. Control box, showing bathythermograph master card.

15.4 OPERATION

Figure 16 is an isometric assembly drawing showing how the simulator is incorporated in the trainer.

To service the simulator, a representative assortment of BT cards was prepared, covering the principal depth-temperature patterns of interest in the training program. On the back of these cards the area on the right-hand side of the depth-temperature trace is painted dead black and the remaining area is left white. The card is mounted on glass with the unpainted side against the glass. One of these cards is inserted in the front panel of the control box, with the glass face outward, as shown in Figures 15 and 17.

A lamp mounted inside the control box focuses a light spot on the back of the card through a series of aligning prisms (Figure 20) and a movable microscope objective. In operation, the light spot is made to straddle the boundary between the black and white parts of the card by means of a servo system, the positioning of which is determined by the amount of light reflected back through the microscope and into a photocell. The microscope-photocell unit is mounted on a carriage which is free to move both vertically and horizontally, thus providing freedom for the light spot to follow the black-white boundary. The vertical position of the carriage corresponds to the depth of the submarine in the ocean and the horizontal position to the temperature.

The microscope-photocell unit is given vertical movement by a selsyn receiver which responds to a selsyn transmitter connected to the depth shaft of the Askania trainer (Figure 16). By this means, the position of the light spot on the card is made to agree vertically with the submarine depth, both as simulated by the trainer and as indicated by the depth lines printed on the BT card.

The horizontal position of the light spot on the card is determined photoelectrically by the particular pattern recorded on the BT card inserted in the machine. The horizontal positioning is effected by a servo-motor system which automatically drives the carriage on which the microscope-photocell unit is mounted toward the black-white boundary and which is satisfied only when the light spot straddles this boundary. The output motor of the servo system is also coupled to the density control shaft of the Askania trainer, so that for each horizontal position of the light spot on the card the appropriate water density is set into the trainer. Accordingly, as the submarine depth changes in response to orders from the submarine commander, the light spot moves vertically to the indicated submarine depth and is driven horizontally so as to follow the contours of the depth-temperature curve; in so doing a change in water density is effected which reacts in a realistic fashion on the behavior of the submarine simulated by the Askania trainer.

A submarine BT is installed in a position convenient for the student diving officer. (An inside view is shown in Figure 18.) By means of selsyn receivers which respond to the depth and temperature selsyn transmitters already described, the mockup BT records the same trace as that shown on the master card inserted in the control box.

15.5 DESCRIPTION

Control Unit. The front panel of the control cabinet, shown in Figure 15, is fitted with a rectangular opening for the master BT card and slots into which the card is inserted. There are also a motor switch and line switch, each with pilot lights and motor current indicating d-c ammeter. Two screwdriver adjustments for the amplifier are placed under the name plate on the front panel. One of these controls the stability of the servo system and the other controls the ratio of the black to white portions of the card seen by the photocell at balance.

Mounted on the base plate of the control cabinet are the amplifier and thyratron chassis, the holding magnet, the motor relay, the saturable core transformer for the light-source voltage regulator, and the track assembly for the microscope-photocell unit (see Figure 17).

Track Assembly. The track assembly consists of a stationary track secured to the control cabinet base plate and having two vertical ways; a vertically movable carriage fitted with rollers which travel up and down along the above ways; and a horizontally movable carriage which moves on rollers fitted to the vertical carriage. All the tracks are of aluminum; the horizontal carriage is in one piece and the vertical carriage consists of a top and bottom plate joined together by two side brackets. One side bracket carries prism No. 2. Prism No. 1 is fastened to the top of the stationary track. On the back of the stationary track is installed an idler gear which engages a rack mounted on the vertical carriage and through which vertical motion is imparted to the vertical carriage by the depth selsyn. On the horizontal carriage are mounted prisms No. 2 and 3 (Bausch & Lomb No. 31-90-92-014), the photocell (RCA922), and the microscope objective (Bausch & Lomb 10.25 mm, 0.40 215TL). Prism No. 3 is mounted slightly to one side, so that although it deflects the light beam through the microscope objective on to the card, part

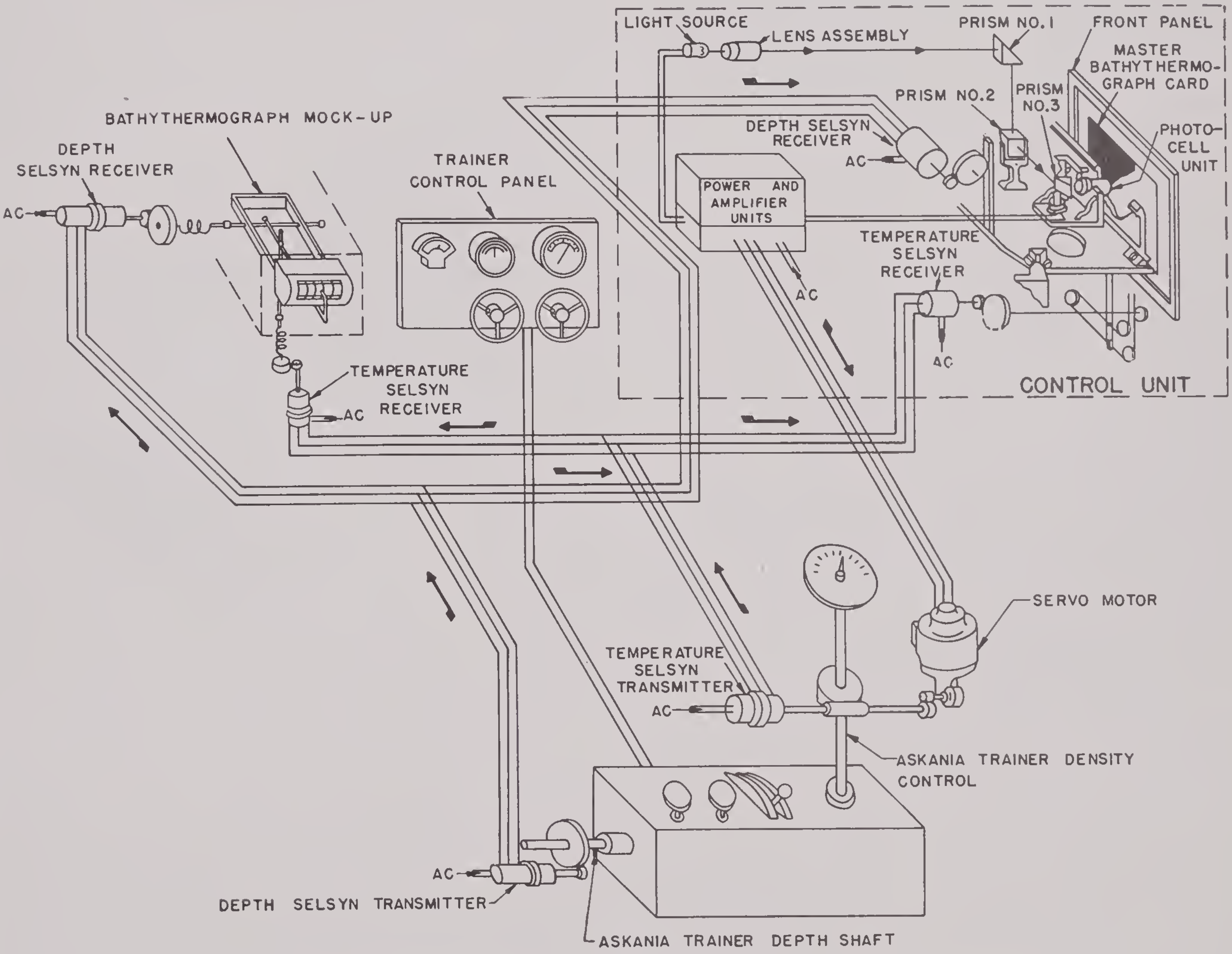

LIGHT SOURCE
LENS ASSEMBLY
PRISM NO. 1
FRONT PANEL
MASTER BATHYTHERMOGRAPH CARD
PRISM NO. 2
PRISM NO. 3
PHOTO-CELL UNIT
DEPTH SELSYN RECEIVER
AC
POWER AND AMPLIFIER UNITS
TEMPERATURE SELSYN RECEIVER
AC
AC
CONTROL UNIT
BATHYTHERMOGRAPH MOCK-UP
DEPTH SELSYN RECEIVER
AC
TRAINER CONTROL PANEL
TEMPERATURE SELSYN RECEIVER
AC
SERVO MOTOR
TEMPERATURE SELSYN TRANSMITTER
AC
ASKANIA TRAINER DENSITY CONTROL
AC
DEPTH SELSYN TRANSMITTER
ASKANIA TRAINER DEPTH SHAFT

FIGURE 16. Bathythermograph simulator, isometric assembly drawing.

of the returning reflection passes the prism and enters the photocell. Two shielded cables lead from the photocell to the amplifier unit. They are clamped to the horizontal carriage and run through a bakelite block on the stationary track.

Elevator Unit. The vertical position of the light spot on the master BT card corresponds to the simulated depth of the submarine in the Askania trainer. The depth selsyn (see Figure 17), mounted behind the stationary track, imparts vertical movement to the vertical carriage through a train of gears which engage the idler gear previously mentioned. The 5F depth selsyn receiver responds to a 5G depth selsyn transmitter, which in turn is driven by the depth shaft of the Askania trainer. To prevent the vertical carriage from dropping because of its own weight when the power is off, a serrated disk is mounted on the selsyn; and a holding magnet operates, through a mechanical linkage, a detent that engages the serrated disk.

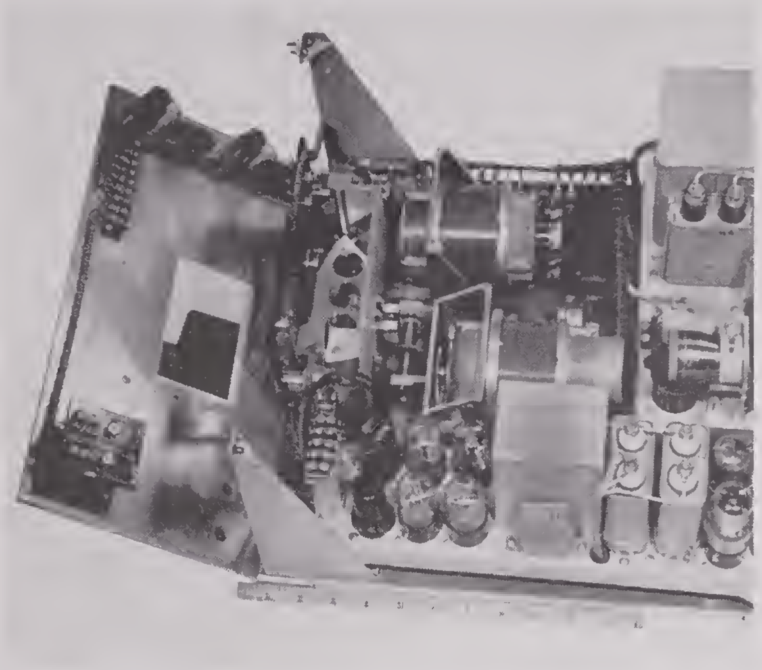


FIGURE 17. Control box, interior view.

Translator Unit. The horizontal position of the light spot corresponds to water temperatures as traced on the master BT card that is inserted in the front panel of the control cabinet. The horizontal movement is controlled by the reaction of the photocell to the reflected light from the card in the following manner. If the light beam is directed against the white portion of the card, the photocell is strongly illuminated by the resulting reflection. As the beam moves across the boundary line between black and white, the illumination will lessen until it reaches a minimum, when the beam is focused entirely upon the black portion. This movement from white to black, or vice versa, thus produces a gradual transition in photocell output. This output is converted by the amplifier and thyratron units into voltages suitable for the reversible servo motor which turns the density control shaft on the Askania trainer. Connected to the motor is a selsyn transmitter to which the temperature selsyn in the control unit responds. (The temperature selsyn, a 5F synchro motor, is mounted behind the stationary frame of the carriage assembly alongside the depth selsyn, as shown in Figure 19.) Through gears and a pulley unit the temperature selsyn imparts horizontal movement to the photocell carriage. If the photocell has excitation corresponding to a black region on the card, the motor will rotate in one direction whereas if the lens is opposite white, the reverse rotation will result. Thus the loop through the photocell, amplifier and power supply, motor, selsyns, and the variable light-reflecting characteristics of the card comprise a servo or

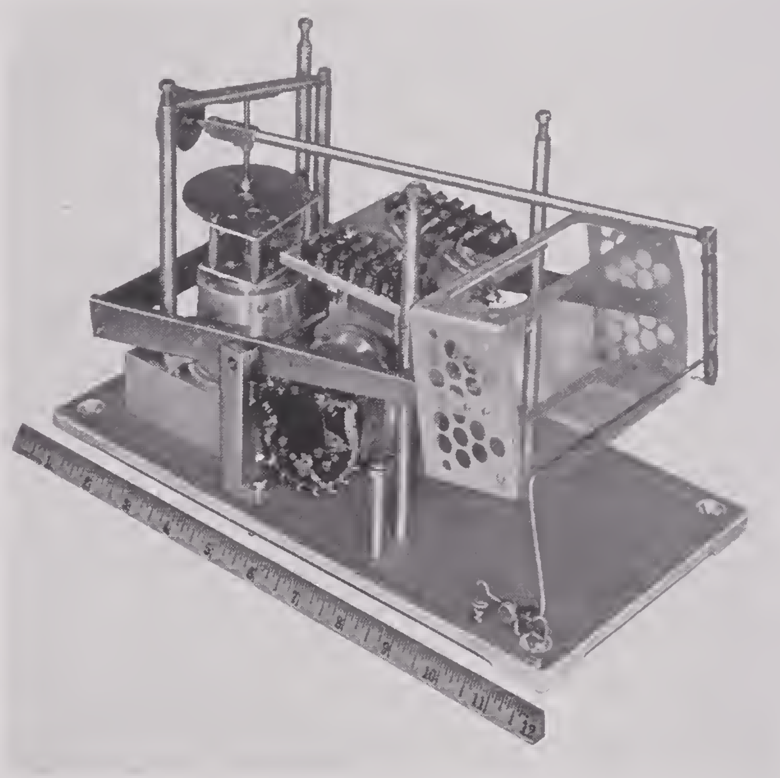


FIGURE 18. Submarine bathythermograph mock-up, inside view.

automatic control loop. The polarities of this loop are such that if the light spot is not on the boundary line between white and black it will move until this condition obtains, at which time the density control shaft on the trainer will have been turned until the density factor in the trainer corresponds to the temperature indicated on the card.

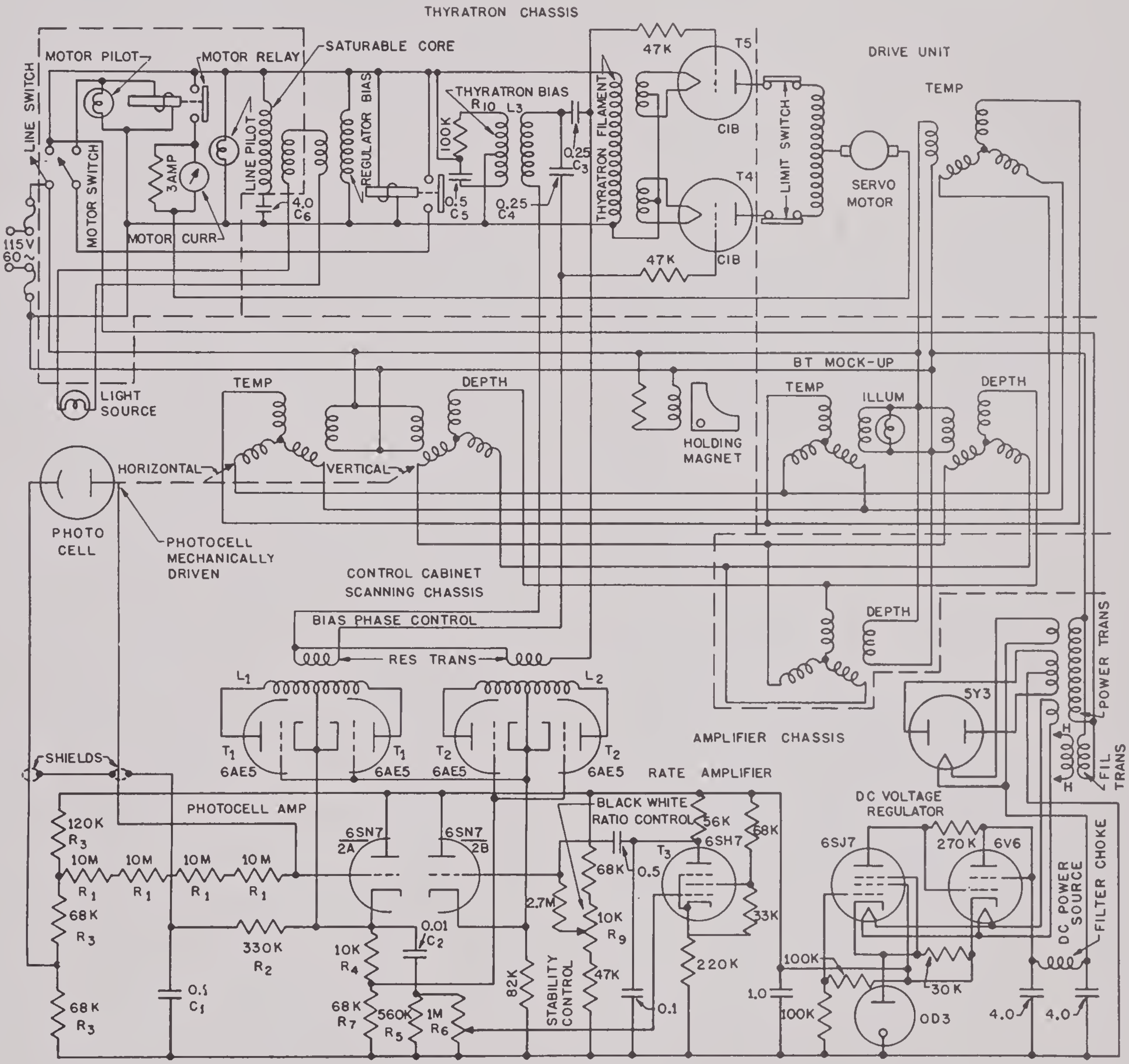

THYRATRON CHASSIS
MOTOR PILOT
MOTOR RELAY
SATURABLE CORE
LINE SWITCH
MOTOR SWITCH
3AMP
LINE PILOT
4.0
C6
REGULATOR BIAS
THYRATRON BIAS
R10
L3
100K
0.5
C5
0.25
C4
0.25
C3
THYRATRON FILAMENT
47K
T5
C1B
T4
C1B
47K
LIMIT SWITCH
SERVO MOTOR
DRIVE UNIT
TEMP
115V
60~
MOTOR CURR
LIGHT SOURCE
BT MOCK-UP
TEMP
DEPTH
HOLDING MAGNET
TEMP
ILLUM
DEPTH
HORIZONTAL
VERTICAL
PHOTO CELL
PHOTOCELL MECHANICALLY DRIVEN
CONTROL CABINET SCANNING CHASSIS
BIAS PHASE CONTROL
RES TRANS
L1
L2
DEPTH
POWER TRANS
5Y3
AMPLIFIER CHASSIS
FIL TRANS
SHIELDS
T1
6AE5
T1
6AE5
T2
6AE5
T2
6AE5
RATE AMPLIFIER
PHOTOCELL AMP
BLACK WHITE RATIO CONTROL
56K
68K
6SH7
T3
DC VOLTAGE REGULATOR
6SJ7
270K
6V6
120K
R3
10M
R1
10M
R1
10M
R1
10M
R1
68K
R3
68K
R3
6SN7
2A
6SN7
2B
330K
R2
0.5
C1
0.01
C2
10K
R4
68K
R7
560K
R5
1M
R6
82K
2.7M
STABILITY CONTROL
68K
0.5
10K
R9
47K
0.1
220K
33K
100K
1.0
100K
30K
OD3
4.0
4.0
DC POWER SOURCE
FILTER CHOKE

FIGURE 19. Servo system schematic.

Lamp Assembly. The light source consists of a Mazda No. 1493 lamp mounted in an aluminum radiator to dispel the heat and a lens unit mounted ahead of the lamp; the entire assembly is secured to a bracket bolted to the control-cabinet base plate. The lens unit is made from a Petzval-type motion-picture projector lens, 2-in. focal length and f 16 aperture, with the Plazzi-Smith field corrector element removed.

Since the photocell response is in proportion to quantity of light, it is important that the light source be kept constant. In order to do this it is necessary to regulate the power supply to the lamp to reduce the effect of variations in line voltage. This is accomplished by means of a voltage regulator which consists of a saturable core transformer, a current minimizing condenser and a bias transformer.

Amplifier and Thyratron Units. The combined function of these two units is to convert the signal from the photocell into the appropriate control for the motor unit which turns the density control shaft on the trainer, and which also, through the temperature selsyns, imparts horizontal movement to the photocell, thus completing the servo system loop. This servo system is illustrated schematically in Figure 19. It operates as follows:

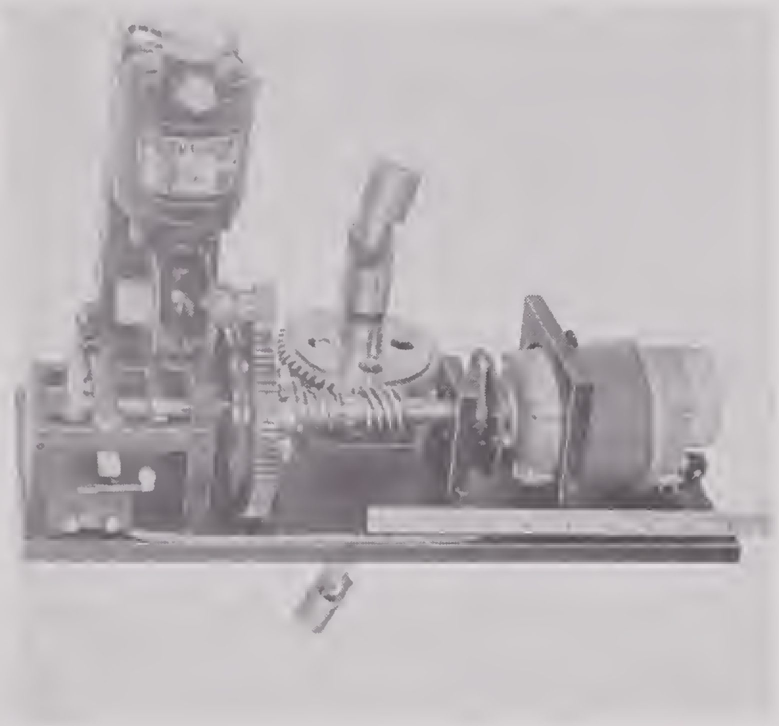


FIGURE 20. Motor unit for the bathythermograph simulator.

1. The signal from the photocell is brought into the amplifier chassis by means of two shielded leads and develops a voltage across load resistors R_1. Resistor R_2 and condenser C_1 provide decoupling for the input shields. Voltage divider R_3 furnishes the photocell with the proper operating potential and supplies bias for tube section 6SN7/2A and the photocell. The IR drop across resistance R_4 supplies voltage for the resistance tubes T_1 and T_2 which are connected in series, with the junction returning to the cathode of tube section 6SN7/2B. Tube T_3 amplifies and applies to the grid of tube 6SN7/2B the first time derivative of the signal from the photocell. This time derivative is generated by condenser C_2, resistor R_5, and control R_6. Its application to the grid is equivalent to applying viscous damping to the mechanical system. Its magnitude is adjusted by control R_8 to a value slightly less than "critical," the value at which all oscillation just disappears. The effective output resistances of transformers L_1 and L_2, which control the firing times of the thyratrons by changing their bias phases, is determined by the grid-to-cathode voltages of the tubes T_1 and T_2. The voltages are in turn determined by the relative cathode potentials of tubes 6SN7/2A and 6SN7/2B. Control R_9 so adjusts the operating point of tube 6SN7/2B that transformers L_1 and L_2 give equal output resistances when the spot is stationary and when it is straddling the black-white boundary. Also located on the amplifier chassis is a d-c, voltage-regulated power supply for tubes 6SN7/2A, 6SN7/2B, T_1, T_2, and T_3.

2. One of two thyratrons on the thyratron chassis controls the current in the servo motor when running forward; the other controls it in reverse. The phase rotating network, composed of condenser C_5 and resistor R_{10} in the primary of the thyratron bias transformer, controls the steady-state current passed by the thyratrons when transformers L_1 and L_2 represent equal resistances. Condenser C_4 and the effective resistance of transformer L_1 make up a phase-rotating network, in the secondary of the thyratron bias transformer, which controls the firing time and therefore the current passed by thyratron T_4. Condenser C_3, transformer L_2, and thyratron T_5, operate in the same manner to produce the opposite direction of motor rotation. When, as a result of a depth change, a change in temperature appears on the BT card, there are three voltage sources that act to change the effective resistances of transformers L_1 and L_2. They are (1) the displacement component from photocell, (2) the velocity component from photocell produced by the differentiating network C_2, R_5, R_6, and (3) a fixed component from control R_9. These operate as previously described to drive the servo motor in such a direction that (1) and (2) are abolished, and balance is restored at the new temperature. Also mounted on the thyratron chassis are a filament transformer for the thyratrons, a time-delay relay to allow filaments to heat, and a bias transformer for the lamp regulator.

Motor Unit. This unit, shown in Figure 20, is mounted beneath the control panel of the Askania trainer. A horizontal shaft running the length of the unit's base plate rotates in two bearing blocks. The servo motor (Bodine Electric Company, NSE 12 RH 1/7 hp), a reversible series-wound d-c motor, mounted vertically above the shaft near one end, turns a spur pinion which engages a split spur gear mounted on the shaft but free to turn on it. To prevent backlash, a lash-lock device is fitted to the gear.

The wedge is clamped to and transmits torque to one section of a friction clutch, the other section being attached to the shaft. The end of the shaft beneath the motor is threaded. A traveling nut on the threaded portion trips a limit switch at each end of its travel and stops the motor. Mechanical stops are also fitted which would slip the clutch if the limit switches failed to operate. This protection is necessary in order to prevent the density control shaft being turned too far.

Near the middle of the horizontal shaft is a worm which engages a worm gear attached to a vertical shaft. This worm gear is fitted with a lash lock similar to the one on the spur gear. The vertical shaft was designed to drive the density control shaft of the Askania trainer. Each end is fitted with universal joint. When the motor unit is installed, a section of the control shaft is cut out and the vertical shaft mentioned above fitted into its place. Thus the servo motor turns the density control shaft by means of the spur gear, friction clutch, worm, and worm gear. On the opposite end of the horizontal shaft from the motor assembly the temperature selsyn transmitter is mounted, resting in a bracket bolted to the base plate, and attached to the horizontal shaft by means of a flexible coupling. This transmitter is a 5G synchro generator.

Bathythermograph Mockup. This unit, shown in Figure 18, is similar in mechanical design to an actual submarine bathythermograph, but the depth and temperature are controlled by two selsyns which respond respectively to the depth and temperature selsyn transmitters connected to the Askania trainer. Thus the depth-temperature record traced on the card is a duplicate of the trace on the master card inserted in the control cabinet. The selsyns in this unit are 1-F synchro motors. Through a train of gears the depth selsyn, mounted near the middle of the base plate, moves the rocker attached to the fiber box and Lucite window, holding the card in such a manner as to impart vertical movement to the card. This corresponds to the submarine's depth. The temperature selsyn, mounted at the end of the base plate farthest from the card, moves, through gears, an indicator arm which extends over the assembly and to which is fastened a vertical arm holding a stylus which rests against the card. By this means horizontal movement corresponding to water temperature is imparted to the stylus. A lamp mounted behind the card illuminates it so that it can be read through the Lucite end panel of the box.

Depth Selsyn Unit. This selsyn is fitted into a bracket, designed to be installed beneath the Askania trainer control panel. When it is so installed, a pinion on the selsyn shaft engages a gear on the trainer depth shaft. The latter gear is a part of the standard trainer equipment. The selsyn is a 5G synchro generator, and the brass pinion, which engages the gear on the trainer, is fitted with a lash-lock device.

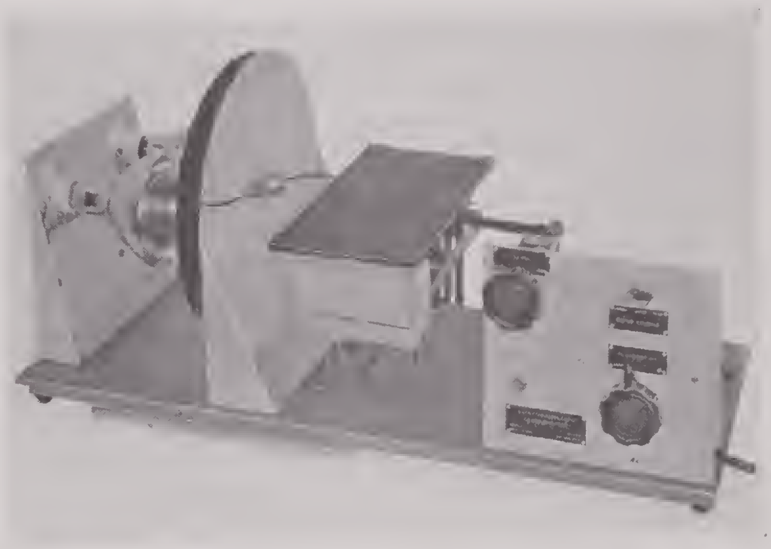


FIGURE 21. Submarine bathythermograph classroom demonstrator, front view.

Submarine Bathythermograph Classroom Demonstrator

The submarine bathythermograph classroom demonstrator [SBCD], developed by UCDWR, is a standard submarine bathythermograph modified by the addition of manual depth and *temperature controls and used to demonstrate the construction and operation of a bathythermograph. The depth control is a small sylphon bellows through which varying pressures can be exerted upon the pressure-sensitive element of the bathythermograph. The temperature control is a long column of liquid, bringing heat to the temperature Bourdon tube of the bathythermograph from an electric heating unit.*

The submarine bathythermograph classroom demonstrator consists of a BT with its cabinet removed, as shown in the center of Figure 21; a bracket holding two 250-watt lamps of the type known as drying lamps, connected in parallel and facing a copper BT temperature tube about 75 ft long wound in pancake form on a spider; and a control panel. All these components are mounted on a base plate, as shown in the figure, with the card of the BT plainly visible to the class.

Figure 22 shows the apparatus on the back of the control panel. The depth knob on the panel operates a copper sylphon bellows fastened to the back of the panel and connected to a pipe. The pipe in turn is connected to the Bourdon tube which actuates the depth movement of the BT stylus. The bellows, pipe, and tube are filled with castor oil, thus forming a hydraulic link by means of which the depth knob moves the card holder vertically. The temperature knob on the panel adjusts a variable autotransformer (a 5-amp, 110-volt, 60-c Variac), which controls the voltage supplied to the lamps. This voltage supply determines the volume of the liquid in the temperature tube, which in turn controls the horizontal movement of the BT stylus. There is also a rapid-change switch, which turns the lamps on or off independently of the Variac. It is used to obtain the maximum rate of temperature change.

15.6 OPERATION

The BT stylus moves horizontally in response to the expansion and contraction of the temperature Bourdon tube, in a manner similar to normal operation at sea, except that the temperature in the SBCD is controlled by the heat from the lamps. The closed capillary tube, wound on a spider and facing the lamps, as previously described, is connected to the temperature Bourdon tube, and the entire system is filled with liquid. Changes in temperature, due to alterations in the lamp voltage, result in changes in volume of the liquid. These changes in volume expand or contract the Bourdon tube so that it moves the stylus in the usual manner of a BT.

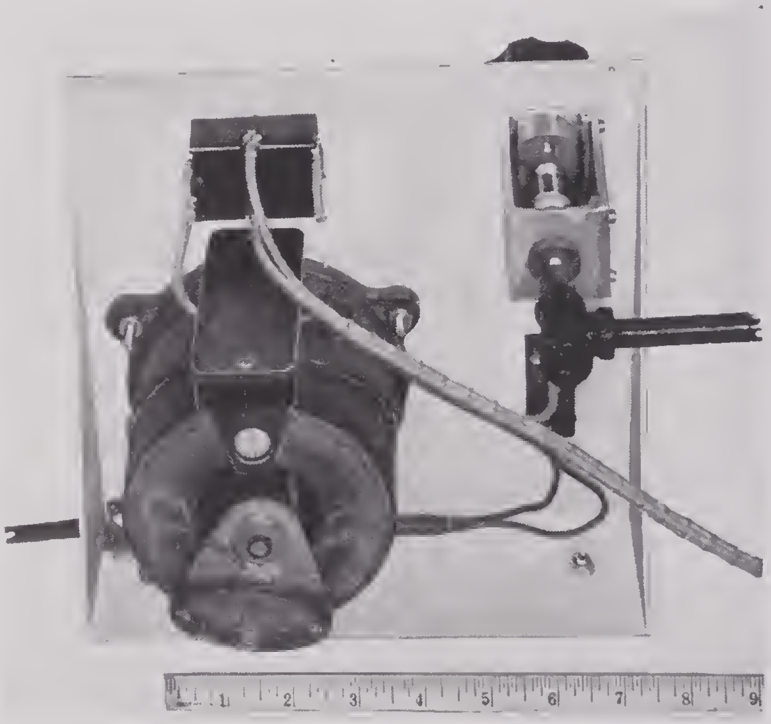


FIGURE 22. Back of control panel.

The card holder, in normal operation of the bathythermograph, moves upward in response to increasing pressure in the depth Bourdon tube, this increasing pressure being due to increasing depth of the submarine. In the SBCD the card holder responds in the same manner, but the pressure is applied by manual operation of the sylphon bellows previously described.

The instructor, at the start of a problem, moves the stylus to any desired temperature by turning the lamps full on with the rapid-change switch. This temperature is then maintained by adjustment of the temperature knob, with the rapid-change switch turned to normal. Thereafter, by adjusting the depth and temperature knobs, the instructor is able to trace on the card any thermal conditions desired, in simulation of actual sea conditions.

Is-Was Animated Trainer

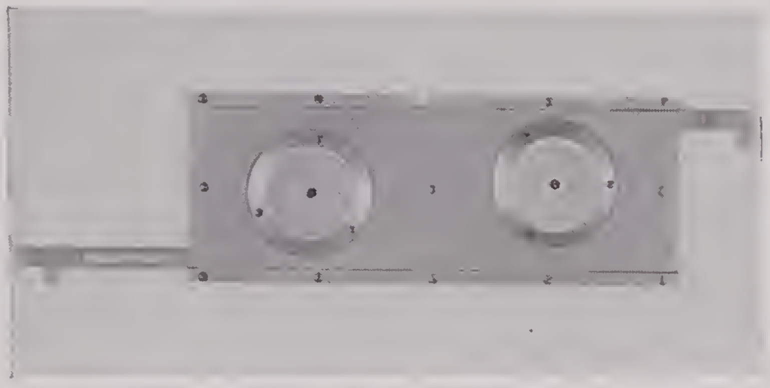


FIGURE 23. IS-WAS animated trainer.

The is-was animated trainer [IS-WAS-AT], developed by CUDWR-NLL, is a lantern slide of the dials of an attack course finder [IS-WAS], with controls which enable the instructor to vary the readings while the slide is in the projector. The images of the dials may be rotated with respect to each other and to the image of an outer fixed dial in a manner similar to the rotation of the dials of an IS-WAS.

GLOSSARY

BT. Bathythermograph.

BDI. Bearing deviation indicator.

Chemical Recorder. An indicator which records range on chemically treated paper.

DCPR. Depth charge pattern recorder.

DRSB. Directional radio sono buoy.

ERGT. Echo recognition group trainer.

ERSB. Expendable radio sono buoy.

FXR. Mechanical noisemaker towed from surface ships to decoy acoustic torpedoes.

GCT. Navy General Classification Test.

GLT. Group listening teacher.

GOT. Group operator trainer.

HUSL. Harvard Underwater Sound Laboratory.

IBM. International Business Machines.

IES Coils. Inductive echo simulator coils, also known as projector simulator [PS] coils.

JP, JT. Submarine sonic listening systems employing magnetostriction line hydrophones.

MAD. Magnetic airborne detector.

Magnetostriction Effect. Phenomenon exhibited by certain metals, particularly nickel and its alloys, which change in length when magnetized, or (Villari effect) when magnetized and then mechanically distorted, undergo a corresponding change in magnetization.

MTB. Maintenance of true bearing.

NLM. Noise level monitor.

OAX Monitor. A portable sound gear monitor, with range from 15 to 26 kc.

OTE. Operator training equipment.

PBT. Primary bearing teacher.

PS Coils. Projector simulator coils, also known as inductive echo simulator [IES] coils.

QC. Standard Navy searchlight-type echo-ranging equipment using magnetostriction transducers.

QFA. Sangamo series underwater sound attack teachers.

QFD. Navy designation for advanced bearing teacher.

QFE. Navy designation for primary bearing teacher.

QFH. Navy designation for primary conning teacher.

QFL. Navy designation for sound range recorder teacher, tactical range recorder teacher or phonograph recorder teacher.

QGB. Navy designation for a particular echo-ranging system utilizing a magnetostriction transducer and incorporating BDI features.

QJB. Navy designation for a Rochelle salt echo-ranging system with BDI.

RCG. Reverberation control of gain.

Reverberation. Sound scattered diffusely back toward the source, principally from the surface or bottom, and from small scattering sources in the medium such as bubbles of air and suspended solid matter.

SASAT. Shipboard antisubmarine attack teacher.

SLC. Simultaneous lobe comparison.

SRGT. Sound recognition group trainer.

TDC. Torpedo data computer.

Transducer. Any device for converting energy from one form to another (electrical, mechanical, or acoustic). In sonar, usually combines the functions of a hydrophone and a projector.

TVG. Time-varied gain.

WCA. Navy designation for a submarine sonar system providing supersonic listening, echo-ranging, and sounding.

WCSS. West Coast Sound School.

WEB. Standard Navy small-sized magnetostriction echo-ranging gear.

WFA. A submarine sonar system providing improved performance over the earlier WCA system.

WHOI. Woods Hole Oceanographic Institution.

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Chapter 9

SHIPBOARD ANTI-SUBMARINE ATTACK TEACHER [SASAT-B]

1. *Shipboard Anti-Submarine Attack Teacher (SASAT B)*, Firth Pierce and Jay Schisel, OSRD 3442, NDRC 6.1-sr30-1402, Report U186, III K 337, UCDWR, Feb. 25, 1944. Div. 6-323.2-M7 For patent information, see Serial 542,504, dated June 28, 1944, Invention Report PC-4 sr-30, Patent 31.

PRACTICE ATTACK METER

2. *A Primary Standard Pressure Gradient Hydrophone*, NDRC C4-sr212-058, Mar. 2, 1942.
3. *"710 A Bone Conduction Receiver,"* M. S. Hawley, *Bell Laboratories Record*, Vol. 18, September, 1939, pp. 12-14.
4. *London Mathematical Society Proceedings*, H. Lamb, Dec. 14, 1882, pp. 50-56.
5. *Vibration Problems in Engineering*, S. Timoshenko, Second Edition, pp. 405-410.
6. *Practice Attack Meter*, OSRD 1367, NDRC, 6.1-sr346-830, BTL, Mar. 25, 1943. Div. 6-323-M1
7. *Some Characteristics of the Sound Field in the Sea*, NDRC C4-sr30-083, UCDWR, Mar. 13, 1942, p. 34.

ECHO INJECTOR

8. *Echo Injector*, Karl Sommermeyer, Report U-302, UCDWR, Mar. 1, 1945. Div. 6-323-M3

SHIPBOARD ANTI-SUBMARINE ATTACK TEACHER (SASAT A)

9. *A Device for Obtaining Bearing and Range Rate to Be Used as an Auxiliary to SASAT A*, Carl Eckart, Report M-82, UCDWR, July 15, 1943. Div. 6-323.2-M1
10. *Shipboard Anti-Submarine Attack Teacher (SASAT A)*, Clark F. Bradley, OSRD 1933, NDRC 6.1-sr30-684, Report U-93, UCDWR, Aug. 30, 1943. Div. 6-323.2-M3
11. *Preliminary Instruction Manual for the Shipboard Anti-Submarine Attack Teacher (SASAT A)*, Clark F. Bradley, and James M. Snodgrass, Report R-94, III K 289, UCDWR, Aug. 31, 1943. Div. 6-323.2-M4
12. *Installation, Operation and Maintenance Instruction Book for Navy Model QFK Shipboard Sound Operator Trainer*, NXss-30773, Stoddart Aircraft Radio Co., UCDWR, January 1944. Div. 6-323.2-M6
13. *Instructor's Manual for Model QFK Shipboard Sound Operator Trainer*, OEMsr-30, Report R-191, UCDWR, March 1944. Div. 6-323.2-M8
14. *Shipboard Anti-Submarine Sonar Trainer (SASAT A), Model V, Final Report*, Edward G. Schmuckler, NDRC 6.1-sr30-1511, Report U211, UCDWR, May 5, 1944. Div. 6-323.2-M9
15. For patent information, see Serial 535,472, dated May 13, 1944, Invention Report PC-4 sr-30, Patent 40.

WEA-1 AND WEA-2 ADAPTERS FOR SASAT A

16. *WEA-1 and WEA-2 Adapters for SASAT*, Clark F. Bradley, Report U-121, UCDWR, Oct. 22, 1943. Div. 6-323.2-M5

SASAT SLIDE RULE

17. *SASAT Slide Rule*, G. P. Harnwell and L. I. Schiff, OSRD 1932, NDRC 6.1-sr30-682, UCDWR, Aug. 13, 1943. Div. 6-323.2-M2
18. For patent information, see Serial 535,472, dated May 13, 1944, Invention Report PC-4 sr-30, Patent 40.
19. *Shipboard Submarine Periscope Attack Teacher*, Gaylord P. Harnwell, UCDWR. Div. 6-325.1-M4

Chapter 10

1. *Preliminary Instruction Book for Model BR-1 Antisubmarine Practice Target Equipment with the Model S1-AB Amplifier. Installation, Operation and Maintenance Manual*, Report U-70, NS-144, UCDWR, June 2, 1943, pp. 15-16. Div. 6-323.3-M7
1a. *Ibid.*, pp. 5-6.
2. *Preliminary Instruction Book for Model BR-1 Antisubmarine Practice Target Equipment with the Model S3-AB Amplifier. Installation, Operation and Maintenance Manual*, Report U-71, NS-144, UCDWR, June 11, 1943, pp. 15-16. Div. 6-323.3-M8
2a. *Ibid.*, pp. 5-6.
3. *Supplementary Notes on Preliminary Instruction Book for Model BR-1 Antisubmarine Practice Target with the Model S3-AB Amplifier*, Report U-71a, UCDWR, Sept. 16, 1943, pp. 1-3. Div. 6-323.3-M9
3a. *Ibid.*, pp. 3-4.
4. *Preliminary Instruction Book for Model SR-2 Antisubmarine Practice Target Equipment. Installation, Operation and Maintenance Manual*, Report U-64, NS-144, UCDWR, May 14, 1943. Div. 6-323.3-M6
5. *Supplementary Instruction Book for Antisubmarine Practice Targets*, OSRD 3806, NDRC 6.1-sr30-1684, Report R-200, NS-144, UCDWR, April 1944. Div. 6-323.3-M11
6. *Echo Repeater Target, Surface Model RR-1,*

Edwin M. McMillan, David J. Evans, and William A. Myers, NDRC C4-sr30-399, Report U-1, UCDWR, Nov. 12, 1942. Div. 6-323.3-M2

7. *Operation, Maintenance and Installation Instructions for Surface Model RR-1 Practice Target*, Report U-15, NS-97, UCDWR, Dec. 14, 1942. Div. 6-323.3-M3
8. *Antisubmarine Practice Target, Keel Model KP-1*, David J. Evans, T. Finley Burke, and Donald G. Reed, Report U-45, NS-144, UCDWR, Feb. 25, 1943. Div. 6-323.3-M5
9. *Towed Submerged Antisubmarine Practice Target, Model SR-2*, David J. Evans, T. Finley Burke, and Donald G. Reed, NDRC 6.1-sr30-736, Report U-42, NS-144, UCDWR, Feb. 25, 1943. Div. 6-323.3-M4
10. *Instruction Book for Model SR-5 Practice Target (Navy Model OAT Practice Target). Installation, Operation and Maintenance Manual*, Report R-142, NS-144, UCDWR, January 1944. Div. 6-323.3-M10
11. For patent information, see Serial 497,232, Invention Reports PC-4 sr-30, Patent 10, and PC-4 sr-30, Patent 51.
12. *Experimental Underwater Towed Model Echo Repeater*, Edwin M. McMillan, William A. Myers, and David J. Evans, NDRC C4-sr30-515, UCDWR, Sept. 1, 1942. Div. 6-323.3-M1
13. *Experimental Surface Model Echo Repeater*, William A. Myers and Edwin M. McMillan, UCDWR, June 20, 1942.

Chapter 11

ARTIFICIAL SONAR PROJECTOR

1. *Inductive Echo Simulator*, O. Hugo Schuck, NDRC 6.1-sr287-901, Report H-145, HUSL, June 28, 1943. Div. 6-321.5-M1
2. *Completion Report on Sound Gear Monitor*, Section 6.1-sr287-2086, HUSL, Nov. 1, 1945.
3. *Neil Handel on Operational Testing Equipment*, Neil E. Handel, HUSL, Oct. 5, 1943. Div. 6-321.6-M1
4. *Projector Simulator Coil Development Aims*, O. Hugo Schuck, HUSL, Feb. 2, 1944. Div. 6-321.5-M2
5. *Projector Simulator Coil Development Aims* (continued from Memorandum of Feb. 2, 1944), O. Hugo Schuck, HUSL, Feb. 10, 1944. Div. 6-321.5-M3
6. *Spherical-Shaped Artificial Projectors*, John O. Hancock, HUSL, Mar. 17, 1944. Div. 6-321.5-M4
7. *Operational Testing and Training Equipment Project Aims*, O. Hugo Schuck, HUSL, Mar. 26, 1944. Div. 6-321.5-M5
8. *Artificial Projector*, John O. Hancock and O. Hugo Schuck, HUSL, May 23, 1944. Div. 6-321.5-M6
9. *Lag Line for Artificial Projector*, John O. Hancock, HUSL, July 26, 1944. Div. 6-321.5-M7
10. *Testing of Artificial Projector*, O. Hugo Schuck and John O. Hancock, HUSL, Sept. 23, 1944. Div. 6-321.5-M8
11. *Distribution of OTE's and Dynamic Demonstrators*, F. V. Hunt, M91.20-238, HUSL, Oct. 21, 1944.
12. *Artificial Projector*, O. Hugo Schuck, John O. Hancock, and B. A. Wooten, NDRC 6.1-sr287-1786, HUSL, Nov. 1, 1944. Div. 6-321.5-M9
13. *Instruction Manual for Artificial Projector*, HUSL, Dec. 1, 1944. Div. 6-321.5-M10
14. *Artificial QC Projector, Model 3*, W. C. Kraft, HUSL, May 8, 1945. Div. 6-321.5-M11
15. *Artificial Sonar Projector*, OSRD 6080, NDRC 6.1-sr287-2054, HUSL, Sept. 1, 1945. Div. 6-321.5-M12

BDI DYNAMIC DEMONSTRATOR

16. *Installation and Maintenance Manual for Bearing Deviation Indicator Unit, Model X-3*, HUSL, Oct. 1, 1943. Div. 6-321.22-M1
17. *Bearing Deviation Indicator Dynamic Demonstrator*, Charles R. Rutherford, B. A. Wooten, and Dwight E. Gray, NDRC 6.1-sr287-1557, HUSL, June 15, 1944. Div. 6-321.22-M2
18. *Bearing Deviation Indicator Dynamic Demonstrator*, NDRC 6.1-sr287-2066, HUSL, June 30, 1945. Div. 6.321.22-M4

OTE-9 (BDI Signal Generator)

19. *Inductive Echo Simulator*, O. Hugo Schuck, NDRC 6.1-sr287-901, Report H-145, HUSL, June 28, 1943. Div. 6-321.5-M1
20. *Operator Training Equipment, Model 9, Bearing Deviation Indicator Signal Generator*, OSRD 5008, NDRC 6.1-sr287-2064, HUSL, Apr. 1, 1945. Div. 6-321.22-M3
21. *Instructor's Manual for the JP-1 Training Program*, Report P50/1197, N-118, CUDWR-NLL, Nov. 2, 1944. Div. 6-321.6-M2

Chapter 12

Recorder Water Noise for the Directional Radio Sonic Buoy Trainer, Glen D. Gillett, Report P52/945, CUDWR-NLL, May 29, 1944. Div. 6-326.3-M1

Filter and Mixer Unit for the Directional Radio Sono Buoy Trainer, Robert T. Zern, Report P52/1037, CUDWR-NLL, July 21, 1944. Div. 6-326.3-M3

Completion Report, Expendable Radio Sono Buoy, NDRC 6.1-sr1128-1581, CUDWR-NLL, July 27, 1944.

Report on Training Activities, Part I, Expendable Radio Sono Buoy; Part II, Directional Radio Sono Buoy, Report P52/1142, covering period from Apr. 1, 1944 to Sept. 1, 1944, CUDWR-NLL, Sept. 25, 1944. Div. 6-326.3-M4

Directional Radio Sono Buoy Trainer, Joseph A. Barkson, OSRD 5095, NDRC 6.1-sr1128-1947, NS-106, CUDWR-NLL, May 1, 1945. Div. 6-326.3-M5

Completion Report, The Directional Radio Sono Buoy, NDRC No. 6.1-sr1128-2224, CUDWR-NLL, May 20, 1945.

Chapter 13

PRIMARY CONNING TEACHER

1. *Primary Conning Teacher*, A. W. Melloh, OSRD 1845, NDRC 6.1-sr30-681, Report U-89, UCDWR, Aug. 14, 1943. Div. 6-322.2-M3

   A Conning Teacher, William E. Stephens, UCDWR, Aug. 29, 1942. Div. 6-322.2-M1

   Instruction Book for Primary Conning Teacher Model QFH, Sangamo Electric Co., June 1943.

   Instructor's Manual for Model QFH Sound Training Equipment (Conning Teacher), Edition B, Report R-192, UCDWR, March 1944. Div. 6-322.2-M4

For patent information, see Serial 511,130, Nov. 20, 1943, Invention Report PC-4 sr-30, Patent 44.

ANIMATED TRAINERS

2. *Instructor's Pamphlet for the Relative Bearing Animated Trainer*, Report P47/936, CUDWR-NLL, July 1, 1944. Div. 6-326.2-M2
3. *Instructor's Pamphlet for the Bearing Indicator Animated Trainer*, Report P47/937, CUDWR-NLL, July 1, 1944. Div. 6-326.2-M1

   Training Equipment for Submarine Personnel, Report G11/913, CUDWR-NLL, May 6, 1944. Div. 6-324-M1

   Animated Trainers BIAT, RBAT and IS-WAS-AT, Glen D. Gillett and Nelson W. Rodelius, NDRC 6.1-sr1128-1598, Report P47/1193, NS-118, NLL, Oct. 31, 1944. Div. 6-326.2-M4

OPERATIONAL BEARING RECORDER

Operational Bearing Recorder, OSRD 3562, NDRC 6.1-sr-287-1454, Report H-261, HUSL, Apr. 10, 1944. Div. 6-326.1-M1

Operational Bearing Recorder, NDRC 6.1-sr-287-2065, NS-97, HUSL, Mar. 1, 1945. Div. 6-326.1-M2

Chapter 14

NOISE LEVEL MONITOR TRAINER

1. *Instructor's Handbook for the Noise Level Monitor Trainer*, Report 4E/M2, CUDWR, 1945 [?]. Div. 6-324-M2

SOUND RECOGNITION GROUP TRAINER

Preliminary Instruction Book for the Sound Recognition Group Trainer, Report M-342, NObs-2074, UCDWR, July 20, 1945. Div. 6-324-M4

RANGE INDICATOR TRAINER

The Range Indicator Trainer, Report M-381, NObs-2074, UCDWR, Dec. 11, 1945. Div. 6-326-M1

GROUP LISTENING TEACHER

Preliminary Instruction Manual for the Group Listening Teacher, Model CXKG (WCA portion), Operation, Installation and Maintenance, Part I, Text; Part II, Illustrations, Report M-380, UCDWR, Mar. 15, 1946. Div. 6-324-M5

Chapter 15

PERISCOPE TRAINER

1. *Periscope Trainer Manual*, N-118, Report P41/1325, CUDWR-NLL, Feb. 5, 1945. Div. 6-325.1-M2

   General Specifications for the Periscope Trainer, NS-97, Report P41/841, CUDWR-NLL, July 11, 1944. Div. 6-325.1-M1

   Periscope Trainer, Joseph A. Barkson, OSRD 5233, NDRC 6.1-sr1128-2213, N-118, Report P41/1420, CUDWR-NLL, May 21, 1945. Div. 6-325.1-M3

   For patent information, see Invention Report PC6.1 sr1128, Patent 76.

CONNING OFFICER ATTACK TEACHER MODIFICATION

2. *Training Equipment for Submarine Personnel*, Report G11/913, CUDWR-NLL, May 6, 1944. Div. 6-324-M1
3. *Synchro Requirements for Attack Teachers*, Glen D. Gillett, Report P40/P52/955, CUDWR-NLL, June 7, 1944. Div. 6-326.3-M2
4. *Conning Officer Attack Teacher*, Glen D. Gillett, NS-257, Report P40/1147, CUDWR-NLL, Sept. 23, 1944. Div. 6-322.2-M5
5. *Preliminary Installation, Operation, and Maintenance Instructions for the Modified Mark 1 Conning Officer Attack Teacher [COAT]*, Report P40/1156, CUDWR-NLL, Feb. 15, 1945. Div. 6-322.2-M6
6. *Modification of the Mark I Conning Officer Attack Teacher*, Glen D. Gillett, Harold Hultgren, and Nelson W. Rodelius, NDRC 6.1 sr1128-1583, Report P40/1227, CUDWR-NLL, Feb. 19, 1945. Div. 6-322.2-M7

TORPEDO ANGLE SOLVER DEMONSTRATOR

7. *Training Equipment for Submarine Personnel*, Report G11/913, CUDWR-NLL, May 6, 1944. Div. 6-324-M1

SUBMARINE BAROMETER SIMULATOR

8. *Submarine Barometer Simulator*, Report M-270, UCDWR, Oct. 28, 1944. Div. 6-325-M1
   For patent information, see Invention Report PC-4 sr-30, Patent 78.

THE BATHYTHERMOGRAPH SIMULATOR

9. *The Bathythermograph Simulator*, Report U360, NObs-2074, UCDWR, Sept. 13, 1945. Div. 6-325.2-M1

SUBMARINE BATHYTHERMOGRAPH CLASSROOM DEMONSTRATOR

10. *Submarine Bathythermograph Classroom Demonstrator*, Report M-363, NObs-2074, UCDWR, Sept. 20, 1945. Div. 6-325.2-M2

IS-WAS ANIMATED TRAINER

11. *Training Equipment for Submarine Personnel*, Report G11 913, CUDWR-NLL, May 6, 1944. Div. 6-324-M1
12. *Instructor's Pamphlet for the IS-WAS Animated Trainer*, Report P47 1000, CUDWR-NLL, July 10, 1944. Div. 6-326.2-M3
13. *Animated Trainers BIAT, RBAT, IS-WAS-AT*, Glen D. Gillett and N. W. Rodelius, NDRC 6.1-sr1128-1598, Report P47/1193, CUDWR-NLL, Oct. 31, 1944. Div. 6-326.2-M4
14. *Training Equipment for Submarine Personnel*, Report G11/913, CUDWR-NLL, May 6, 1944. Div. 6-324-M1

GENERAL

Test-Retest Reliability of Pitch Discrimination Tests, William D. Neff, CUDWR-NLL, Dec. 14, 1942. Div. 6-311-M4

Installation, Operation and Maintenance Instructions for Model QFH Underwater Sound Equipment, Type CAN-55117 Conning Teacher, NXss-29059, Sangamo Electric Co., June 1943. Div. 6-322.2-M2

Phonograph Recordings for Chapter 3

In a number of cases preliminary editions of recordings were issued. These are not listed separately but are mentioned under the headings for the final editions. Distributor and year of issue are given in parentheses.

1. Demonstration Records: Echo Ranging Training Set (NavPers 11401 RA through 11404 RB, 1943).
   10 basic training records explaining echo ranging and doppler effect.
2. Attack Procedure Records: Echo Ranging Training Set (NavPers 11460 RA through 11460 RB, 1943).
   8 records consisting of transcriptions of practice attacks made by a well-trained sonar team, using cut-on procedure (prior to BDI).
3. Exercise Records: Echo Ranging Training Set (NavPers 11430 RA through 11435 RB, 1943).
   2 records for practice in search procedure and 5 for practice in crossing target (dummy gear required). 5 records for practice in echo identification.
4. Listening Records: Sonar Training Set (NavPers 11445 RA through 11448 RA, 1944).
   4 records of torpedo sounds and 3 records of FXR sounds, as heard over standard echo-ranging gear.
5. Doppler Drill Records: Echo Ranging Training Set (NavPers 11415 RA through 11422 RA, 1944).
   Each series consists of a drill of 72 items and a test of 40 items. All items were made from sea-recorded reverberations and synthetic echoes.
   Series D-1: Elementary training; differences of 0, 30, 60, 75 cycles.
   Series D-2: Intermediate training; differences of 0, 14, 30, 45 cycles.
   Series D-3: Same as D-2 with background water noise added.
   Series D-4: Advanced training; background water noise and attenuated echoes.
   The D-Series of doppler drills and tests replaced the earlier series made by CUDWR and issued by BuAer (CS088894 through CS088899) in 1943. The BuAer series used sounds from the advanced bearing teacher.
6. Sonar Pitch-Memory Test (NavPers 11750 RA through 11751 RB, 1944).
7. ASRB Recordings (CUDWR Series ASRB, Records 1 through 17, 1943).
   A series of experimental recordings for training operators of the anchored radio sono buoy equipment. 11 records are demonstrations of underwater sounds; 6 are tests of sound recognition.
8. Expendable Radio Sono-Buoy Training Records (BuAer Device 15P3, Records I through XX, 1944).
   14 demonstration records of sounds heard over ERSB. 2 target identification and turn count test records. 4 records for giving pencil-and-paper search problems. These records replaced the D-16 series of ERSB recordings made and distributed by CUDWR in 1942.
9. Directional Radio Sono-Buoy Training Records (CUDWR DRSB Series, Records 1 through 10, 1944).
   10 demonstration records for training operators in special features of DRSB. The ERSB training records were also used in DRSB training.
10. QFL Trainer Recordings (NavPers 11510-11518; 11522-11530; 11534-11542; 11546-11554; 11558-11566, 1944).
    Recordings of practice attacks on submarines, with 75-cycle tone added to key the recorders. Usable only with QFL trainer. Contents are tabulated below:

Quantity of records	Subject matter
12	Basic explanations of recorder operation and trace interpretation
4	Demonstrations of changing target aspect
2	Tests on target aspect change
3	Demonstrations of knuckles and pillenwerfer

3	Range rate and doppler drills
10	Firing time drills, cut-ons, ahead thrown attacks
6	Firing time drills, BDI, ahead thrown attacks
3	Firing time drills, depth charge attacks
2	Final test

11. ERGT Trainer Recordings (UCDWR, 1945).
    Drill records for training in echo recognition. While designed for use with the ERGT, they may also be used by a trained instructor without the ERGT. Series ERT-3 replaced two earlier experimental series. Contents of ERT-3:

    Subject matter

    Doppler training
    Contact classification
    Faint echo detection
    Cut-on drills
    Procedure drills
    Achievement tests on doppler, contact classification, faint echo detection

Slides and Films

1. Sighting Subs by Sound (SN-2637 a, b, c, 1943).
   Slide film in 3 parts for ERSB instruction. Accompanied by disk recordings.
2. Directional Radio Sono Buoy (CUDWR, 1944).
   Sound movie on operation and use of DRSB.

Devices for Classroom Use

1. Magnetic Ocean (UCDWR, 1944).
   8-in. ASW vessels and 6-in. submarine held magnetically to a 4x4 ft iron sheet. Elastic cord connecting ship and submarine permits continuous demonstration of relative bearing and target angle. 11 units constructed for use at West Coast Sound School.
2. Relative Bearing Animated Trainer (CUDWR, 1944).
   Lantern slide representing a relative bearing scale.
3. Bearing Indicator Animated Trainer (CUDWR, 1944).
   Lantern slide representing the bearing repeater dials of a sonar stack.

Phonograph Recordings for Chapter 5

In a number of cases preliminary editions of recordings were issued. These are not listed separately but are mentioned under the headings for the final editions. Distributor and year of issue are given in parentheses.

1. JP Sonic Listening Records (NavPers 11720RA-11731RB, 1944).
   8 records of general instruction and demonstration; 10 records on turn counting, including drills and tests; 6 drill and test records on recognition of target and nontarget sounds. Replaced the JP-1 Training Recordings, Series A, distributed by CUDWR, 1943.
2. WCA Training Records (NavPers 11585RA-11592RB, 1944).
   4 records of general instruction and demonstration; 4 records on turn counting, including drills and tests; 8 demonstration, drill, and test records on recognition of target and nontarget sounds.
3. SRGT Recordings (UCDWR, 1945).
   Over 100 drill and test records covering such fields as target classification, target differentiation, echo-ranging detection, contact detection, turn counting and bow-stern identification; prepared for use with the sound recognition group trainer, but may be used independently if administered by a trained instructor.
4. Target Discrimination Recordings (CUDWR, 1945).
   9 drill and 3 test records presenting exercises as follows: sound of ship's screws given as sample, then series of identical and very similar sounds from which student must pick out original sample.
5. Submarine Telephone Talker Recordings (CUDWR, 1944).
   Two records, the first containing examples of telephone talking as recorded over a submarine battle circuit during practice operations, the second pointing out typical errors made in the first and demonstrating correct procedures.
6. QFM Trainer Recordings (CUDWR, 1944).
   3 records, distributed only with QFM trainer, containing examples of torpedo runs as recorded over TDM equipment, 60-c tones inserted at appropriate intervals to key the recorders.
7. NLM Trainer Recordings (CUDWR, 1944).
   4 records of auxiliary sounds and background water noise to be played through the control unit of the trainer in order to produce appropriate readings on the NLM; records distributed only with NLM trainer.

Slides and Films

1. The Fundamentals of Sound, Parts I and II (U. S. Navy Training Films SN 4090A and 4090B; distributed by BuAer, 1944).
   Slide films with accompanying sound on records; Part I describes sound waves and their method of transmission, Part II covers refraction, reflection, and doppler effect.
2. Estimation of Angle-on-the-Bow, Parts I-V (U. S. Navy Training Films SN 4091 a, b, c, d, e, distributed by BuAer, 1944).
   Silent slide films for training of submarine officers, replacing lantern slides originally used for this purpose.
3. Instructional Slides for Submarine Training (numbers shown below distributed by BuAer, 1944).
   Mainly reproductions of wall charts and diagrams. Contents include:

Quantity of slides	Identifying numbers	Subject matter
49	LN 4069 a-aw	General
16	LN 4071 a-p	Torpedoes

34	LN 4073 a-ai	Engineering — Auxiliaries
21	LN 4075 a-u	GM, V-16, 278A Diesel
21	LN 4075 v-ap	GM, 8-268A Diesel
25	LN 4077 a-y	Fairbanks Morse Engine
16	LN 4079 a-p	Engineering miscellaneous
36	LN 4081 a-aj	Electrical
30	LN 4083 a-ad	Communications

4. Lantern Slides for Sonar Training (CUDWR, 1944).

   Used in basic classroom instruction, operation and maintenance. Separate set for each of the following equipments:

Equipment	Quantity of slides
JP	26
WCA	14
JT	20
NLM	5
TDM	5
DCDI	4

Classroom Devices

1. Torpedo Angle Solver Demonstrator (CUDWR, 1944).

   Large scale model of standard angle solver; one unit constructed for Submarine School.

The following were animated lantern slides with movable dials for altering the image shown on the screen. Seven units of each were constructed for the Submarine School and other activities.

2. Relative Bearing Animated Trainer (CUDWR, 1944).
3. IS-WAS Animated Trainer (CUDWR, 1944).
4. Bearing Indicator Animated Trainer (CUDWR, 1944).

Instruction Books for Chapter 3

Distributor and date of issue are shown in parentheses. For laboratory developments only the most recent issues of instruction books are listed; in some instances these were preceded by temporary publications which are now obsolete.

Sonar Operation

1. *Operation of the Sound Range Recorder* (COMINCH, March 1944).

   A general manual, prepared by CUDWR and ASDevLant, covering all phases of recorder operation and trace interpretation. Preceded by a preliminary handbook on the interpretation of recorder traces, written and issued by CUDWR in 1943.
2. *Operator's Manual for BDI Unit, Model X-3* (HUSL, October 1943).
3. *Preliminary Manual—Operation and Use of the Expendable Radio Sonic Buoy Equipment* (CUDWR, April 1943) (D16/R188).
4. *Operator's Manual for the Directional Radio Sono Buoy* (CUDWR, December 1944) (D34/R1260).

Sonar Maintenance

1. *Notes on Servicing Radio and Sound Equipment* (BuShips, December 1942).

   Preliminary sonar maintenance manual developed from notes used at the West Coast Sound School.
2. *Sonar Material Handbook* (COMINCH, February 1943).

   The first general text and reference covering the maintenance of underwater sound equipment.
3. *Sonar Bulletin* (BuShips, first issue October 1943).

   Issued at intervals to present new material on maintenance. UCDWR aided in preparation of the first four issues.
4. *Sonar History Record* (West Coast Sound School, March 1944).

   Contained blank forms which, when properly filled out, constituted a complete history of the installation and subsequent performance of the item of sonar equipment to which the book was assigned. Later replaced by the Sonar Equipment Log.
5. *Suggested Guide for Upkeep of Sonar Equipment* (WCSS, March 1944).

   Step-by-step maintenance procedures for routine upkeep of echo-ranging equipment aboard ship. Prepared for local use, it was later printed in the 4th issue of the Sonar Bulletin.
6. *Sonar Maintenance Handbook* (BuShips, August 1944).

   An exhaustive loose-leaf book covering maintenance of all types of ASW sonar equipment. The first complete instruction book of its kind.
7. *Installation and Maintenance Manual for BDI Unit, Model X-3* (HUSL, October 1943).

   Later replaced by *Maintenance Manual for BDI Equipments*, prepared under Project NS-252.
8. *Preliminary Manual—Installation and Maintenance of the Expendable Radio Sonic Buoy Equipment* (CUDWR, April 1943) (D16/R237).
9. *Preliminary Handbook of Maintenance Instructions for Radio Transmitting Equipment AN/CRT-4 (XN-1)* (CUDWR, November 1944) (D34/R1169).

   For Directional Radio Sono Buoy transmitting equipment.
10. *Installation and Maintenance Instructions of Receiving Equipment AN/ARR-16* (CUDWR, November 1944) (D34/R1167).

    For Directional Radio Sono Buoy receiving equipment.

The following manuals were prepared under Project NS-252 (UCDWR in collaboration with BuShips). Some of them were issued after Division 6 participation had ended.

11. *Sonar Equipment Log.*
12. *Maintenance Manual for QCS/QCS-1/QCT/QCT-1/QCQ-1/QCR-1 Sonar Equipment.*
13. *Maintenance Manual for QCQ-2 Sonar Equipment.*
14. *Maintenance Manual for BDI Sonar Equipment.*
15. *Maintenance Manual for WCA Sonar Equipment.*

16. *Maintenance Manual for QBE/QBE-1/QBE-3/QBE-3a Sonar Equipment.*
17. *Maintenance Manual for WEA-2/WEA-2a Sonar Equipment.*
18. *Maintenance Manual for Sonar Crystal Projectors.*

Radar and Radio

The following manuals were prepared under Project NS-252.

1. *Radar Equipment Log.*
2. *Radio Equipment Log.*

Bathythermograph

1. *Calculation of Sound Ray Paths Using the Refraction Slide Rule* (NavShips 943, May 1943).
2. *Prediction of Sound Ranges from Bathythermograph Observations* (NavShips 943-C2, March 1944).

The following manuals were part of the program of Project NS-308 (UCDWR in collaboration with BuShips). Although most of them were issued after Division 6 participation had ended, the entire list is given here.

3. *The Sonar Range Book* (NavShips 900,040, June 1944).
4. *Manual for Bathythermograph Pilot Instructors* (UCDWR, M-250, September 1944).
5. *Herald Ranges* (NavShips 900,070, May 1945).
6. *Sound in the Sea* (NavShips 900,112).
7. *Rules for Predicting Maximum Echo Ranges* (NavShips 900,111).

Magnetic Airborne Detector

1. *Signal Recognition Manual AN/ASQ-1 and AN/ASQ-1A in Airplanes* (Airborne Instruments Laboratory, April 1944). 6.1-sr1129-1383.
2. *Handbook of Maintenance Instructions for CP-2ASQ-1 and CP-2/ASQ-1A Equipment* (Airborne Instruments Laboratory, May 1944). 6.1-sr1129-1386.

Instruction Books for Chapter 5

Only the most recent issues of instruction books are listed; in some instances these were preceded by temporary publications which are now obsolete. Distributor and date of issue are shown in parentheses.

Sonar Operation

1. *Submarine Sonar Operator's Manual* (NavPers 16167, November 1944).
   Standardized procedures for the operation of sonar equipment on submarines.
2. *Topside Listening* (CUDWR, January 1944) (D24/R626).
   Operator's Manual for JP sonic listening equipment.
3. *Operator's Manual for JT Sonar Equipment* (CUDWR, May 1945) (D55/R1401).
4. *How to Operate the Cavitation Indicator and Noise Level Monitor* (CUDWR, July 1945) (P55/TG156).
5. *Operator's Manual for the Torpedo Detection Modification of WCA-2 Equipment* (CUDWR, March 1945) (P60/R1316).

Sonar Maintenance

1. *Maintenance and Trouble-Shooting Instructions for Models JP-1, JP-2, and JP-3 Sound Receiving Equipment* (CUDWR, May 1944) (D24/R837).
   A preliminary manual used in JP training programs; later replaced by *Maintenance Manual for JP-1/JP-2/JP-3 Sonar Equipment*, prepared under Project NS-252.
2. *Preliminary Installation Instructions for Model JT Sonar Equipment* (CUDWR, May 1945) (D55/R1314).
3. *Preliminary Manual: Installation, Operation, and Maintenance of the Depth Charge Direction Indicator* (CUDWR, December 1943) (D50/R614).
4. *Preliminary Installation and Maintenance Instructions for the Depth Charge Range Estimator* (CUDWR, February 1945) (D50/R1394).
5. *Preliminary Installation and Maintenance Instructions for the Noise Level Monitor and Cavitation Indicator* (CUDWR, February 1945) (P55/R1192).
6. *Preliminary Handbook of Installation, Operation, and Maintenance Instructions for the Torpedo Detection Modification of the WCA-2 Sonar Equipment* (CUDWR, February 1945). (P60/R1316).

The following manuals were prepared as part of Project NS-252 (UCDWR in collaboration with BuShips) and some of them were issued after Division 6 participation had ended.

7. *Maintenance Manual for WCA/WCA-1 Sonar Equipment.*
8. *Maintenance Manual for WCA-2 Sonar Equipment.*
9. *Maintenance Manual for JP-1/JP-2/JP-3 Sonar Equipment.*

Sonar Instructor's Manuals

1. *Preliminary Instructor's Manual for the JP-1 Training Program* (CUDWR, November 1944) (P50/R1197).
2. *Training Program and Instructor's Manual for ComSubsLant Sonar-Radar Training Barge (YNg-22)* (CUDWR, January 1945) (P63/R1308).
3. *Instructor's Notes for First Week of Sonar Operator's Course Given by Pre-Commissioning Group, New London, Connecticut* (CUDWR, February 1945) (P63/R1415).
4. *Outlines of Lectures on the Noise Level Monitor and Cavitation Indicator* (CUDWR, February 1945) (P55/R1341).
5. *Outline of Training in the Use of Torpedo Detection Modification of WCA-2 Equipment* (CUDWR, February 1945) (P60/R1369).
6. *Outline of Instruction on the Depth Charge Direction Indicator* (CUDWR, February 1945) (D50/R1355).

Voice Communications

1. *Submarine Telephone Talker's Manual* (NavPers 16171, December 1944).
   Textbook for elementary instruction of submarine personnel in voice communication procedures.
2. *Standard Submarine Phraseology* (CUDWR, January 1945).

An official publication of standardized voice procedures and phraseology; distributed by ComSubsLant.

3. *Ship's Organization Chapter on Voice Communications* (CUDWR, January 1945).
   Distributed by ComSubsLant to be inserted in ship's organization book of each submarine.
4. *Instructor's Handbook for Basic Course in SubMarine Voice Communications* (Harvard Psycho-Acoustic Laboratory, December 1944).

Radar

1. *Fundamentals of Radar* (CUDWR, February 1945) (P49A/R1389).
2. *Submarine Radar Operator's Course* (CUDWR, December 1944) (P63/R1267).

Bathythermograph

1. *Reference Textbook for Submarine Bathythermograph Field Engineers* (WHOI, November 1944).
2. *Lecture Notes on Use of Submarine Bathythermograph* (WHOI, July 1945).
   This replaced earlier edition published by WHOI in January 1944.

The following manuals were prepared by WHOI and UCDWR in collaboration with BuShips:

3. *Use of Submarine Bathythermograph Observations* (NavShips 943-F, July 1943).
4. *Use of the Bathythermograph as an Aid in Diving Operations* (NavShips 900,018, February 1944).

The following manuals were prepared by Project NS-308 (UCDWR in collaboration with BuShips). All were completed after Division 6 participation had ended.

5. *Use of Submarine Bathythermograph Observations* (NavShips 900,069).
   Issued in seven sections with a loose-leaf binder; constituted a complete revision of NavShips 943-F of similar title.
6. *The Sea for Submarines* (NavShips 900,018).

CONTRACT NUMBERS, CONTRACTORS, AND SUBJECT OF CONTRACTS

Contract Number	*Name and Address of Contractor*	*Subject*
OEMsr-20	The Trustees of Columbia University New York, New York	Studies and experimental investigations in connection with and for the development of equipment and methods pertaining to submarine warfare.
OEMsr-1128	The Trustees of Columbia University New York, New York	Conduct studies and experimental investigations in connection with and for the development of equipment and methods involved in submarine and subsurface warfare.
OEMsr-1129	The Trustees of Columbia University New York, New York	Conduct studies and experimental investigations in connection with the development and research work involving the application of magnetic methods to antisubmarine warfare including the development of airborne equipment and methods for training personnel in the use of such magnetic methods, establishing the necessary laboratories and facilities for this purpose.
OEMsr-30	The Regents of the University of California Berkeley, California	Maintain and operate certain laboratories and conduct studies and experimental investigations in connection with submarine and subsurface warfare.
OEMsr-31	Woods Hole Oceanographic Institution Woods Hole, Massachusetts	Studies and experimental investigations in connection with the structure of the superficial layer of the ocean and its effects on the transmission of sonic and supersonic vibrations.
OEMsr-287	President and Fellows of Harvard College Cambridge, Massachusetts	Studies and experimental investigations in connection with (i) the development of equipment and devices relating to subsurface warfare.

SERVICE PROJECT NUMBERS

The projects listed below were transmitted to the Executive Secretary, NDRC, from the War or Navy Department through either the War Department Liaison Officer for NDRC or the Office of Research and Inventions (formerly the Coordinator of Research and Development), Navy Department.

Service Project Number	*Subject*
N-118	Assistance in the submarine training program.
Ext. NA-120	Construction of a magnetic attack trainer.
NS-97	Selection and training program for sound operators.
Ext. NS-106	Buoy operator trainer for the ERSB.
Ext. NS-142	Request that a bearing deviation indication attachment be provided for attack teacher AirASDEVLANT.
Ext. NS-142	7 models of a dynamic demonstrator (for training in the operation of the BDI), consisting in part of an artificial projector and Navy type OAX monitor.
NS-144	Echo repeater target.
NS-152	Shipboard attack teacher.
Ext. NS-152	Training device, SASAT B Model II.
NS-173	Consulting services on SASAT Mark III equipments.
NS-233	Primary listening teacher.
NS-240	Consulting service on shipboard antisubmarine attack trainer.
Ext. NS-240	Consulting services to Librascope, Inc., on its development of a modification of the SASAT.
NS-245	Advanced listening teacher.
Ext. NS-245	Development and construction of group listening teacher.
NS-252	Preparation of supplements to sonar instruction books.
NS-257	Listening adjunct to submarine attack teacher.
NS-308	Sonar-surface and submarine bathythermograph instruction program.
NS-324	Sonar group operator trainer (2 units of).
NS-325	BDI modification of the QFD advanced bearing teacher (Operational test equipment Model 8) 25 units of for service test from Underwater Sound Laboratory, Harvard, through a subcontractor.
NS-326	Artificial projector for operator training on shipboard monitor equipment Model OAX, 10 units of.
NS-339	Recognition recorder for use in training operators to recognize various ship and torpedo noises, four models of.
NS-342	Attack teacher for QH type scanning sonar equipment.
SC-64	Development and construction of expendable radio sonic buoy training device.

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